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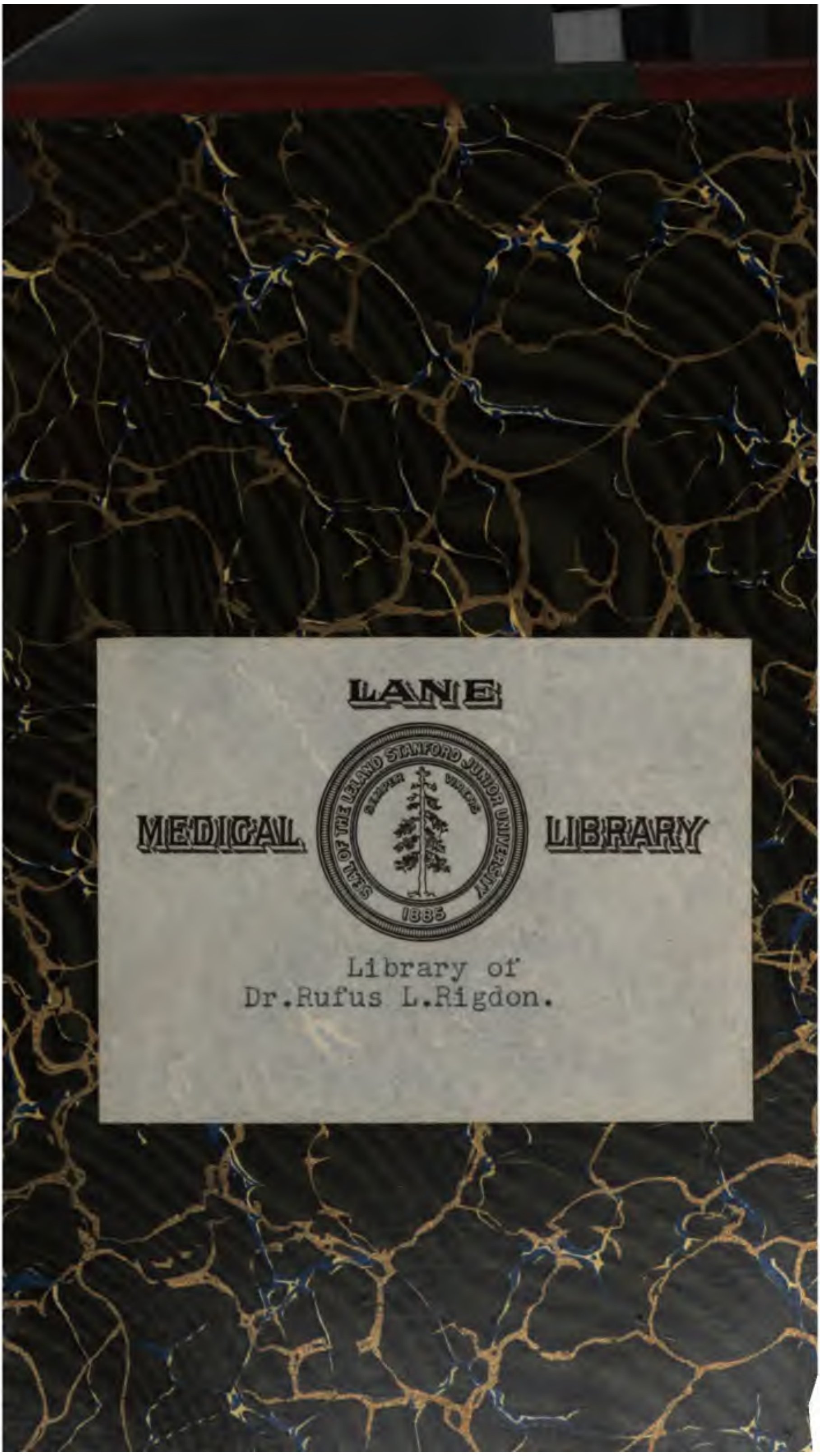

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PHYSICS OF ROENTGEN RAYS

SKIAGRAPHY

PRACTICAL APPLICATIONS OF ROENTGEN RAYS

PHYSICS OF LIGHT AND CAUTERY

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THE PHYSICS OF ROENTGEN RAYS.

INTRODUCTION.

1. As this is written with the specific purpose of explaining the production and utilization of the Roentgen rays for practical purposes only, it is not the intention to go into the theory or history of the apparatus required, but rather to limit the descriptions to *how* to use the same, instead of finding out *why* it acts in this or that manner. This does not mean that no explanation whatever will be given of the various apparatus used, but, rather, that such descriptions will be limited to the elucidation of the most essential parts.

So many methods and instruments have been used and recommended for Roentgen ray work that to do justice to these, even by a most condensed description, would only be confusing to the student, and would prevent him from fastening his attention to the more important parts. Fortunately, during the last year there has been a very active weeding-out process in operation, with the result that the efforts toward improvement and progress have been crystallized more or less around the vital points, instead of wasting energy and expense in seeking advantage in methods that, in reality, would be in a retrograde direction. In consequence of this elimination of non-successful apparatus, it will be easier for the student to get a free view over the field and to avoid instruments that, though made at a large expense and for which great claims may be made, in reality, are less serviceable than cheaper instruments built on more rational principles.

2. Classification of Apparatus.—To facilitate the understanding of the leading principles in Roentgen ray work, we will,

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before proceeding to a more detailed description of apparatus, first give a general view of the whole *modus operandi.*

The Roentgen rays, which proceed from a vacuum tube, are in reality the final transformation of electric energy, derived from any suitable source. First, then, we require means for converting mechanical or chemical energy into electric energy or an opportunity for receiving such energy already at hand.

1. *Sources of Electric Energy.*—Among these may be counted ordinary voltaic cells, accumulators, dynamos, and, derived from the latter on a larger scale, the ordinary street current as used for lighting purposes. Finally, the static induction-machine.

This energy, delivered in the form of an electric current, except that derived from a static machine, is not in a condition and has not the properties requisite for the production of Roentgen rays. It has to be changed, or transformed, and for this purpose sent through what are termed *transformers.*

2. *Transformers.*—Among these the induction-coil occupies the first place. By its means the current of low pressure is changed into an intermittent one of many times higher pressure. With the static machine no transformer is required, as the current derived from it is already in possession of so large a pressure that a further increase of the same is unnecessary.

Having obtained an electric current of the requisite pressure and volume, it will now have to be transformed into Roentgen rays by means of the Roentgen ray tube.

3. *Roentgen Ray Tube.*—This receives the electric current and transforms it into ether waves of extremely high frequency, much higher than ordinary light, and of much shorter wave-lengths. We have then Roentgen rays.

These, in themselves, are invisible to the human eye, and means must be found to change their wave-lengths into a form to which the eye is able to respond. Various salts are able to do this and when they are used as a coating on screens of suitable form, we have what is termed a *fluorescent screen.*

4. *Fluoroscope.*—A screen placed at one end of a tapering box with an aperture at the other end, allowing the eyes to observe the screen and preventing ordinary light from reaching

either the rear side of the screen or the eyes, constitutes what is ordinarily called a *fluoroscope*. Large screens are also used separately; then the whole room must be darkened. The utilization of the fluoroscope in examining the conditions and actions of parts of the human body is called *fluoroscopy*. When it is a question of recording the shadows made visible by the fluoroscope, we have to deal with *skiagraphy*.

5. *Skiagraphy.*—This process is, in reality, simply photographic, because the means used in recording the shadows are the ordinary sensitive plates used in every-day photography. Many of the plates used are especially made for Roentgen ray work, but even then the process of developing and fixing are identical with those of ordinary photography. The final process of reproducing the negative on various photographic printing papers comes under the head of pure photography, but will be included here so as to describe the Roentgen ray manipulations in their entirety.

SOURCES OF ELECTRICAL ENERGY.

VOLTAIC CELLS.

ELECTRICAL UNITS AND TERMS.

3. Pressure and Rate of Flow.—Before proceeding to consider the various voltaic cells, it may be well to first mention the main properties of the electric current. The amount of electrical energy of which the current may be in possession depends on two factors, *pressure* and *rate of flow*. The comparison of a current of electricity with a current of water may assist in understanding the influence of these factors on the character of the current.

For instance, a high waterfall may send a relatively small quantity of water through a tube and supply a small turbine or Pelton waterwheel below with several hundred horsepowers. On the other hand, we may see a river with a low dam sending a large volume of water through several large turbines. The power developed in either case may be the same, but what the latter arrangement lacks in pressure it has to make up in the rate of flow.

In the flow of the electric current, we find these same differences caused by pressure and rate of flow. For some purposes, as, for instance, operating a Roentgen ray tube, a current is required of very high pressure, and relatively small strength, while for others, such as electroplating, a current of great strength, but of very low pressure, is more suitable.

4. Electromotive Force.—While the term *pressure* is largely used when referring to an electric current, it is customary to also use the terms *voltage*, *tension*, and *electromotive force*. The latter is usually abbreviated to E. M. F. As a unit for measuring the pressure, the *volt* is used, and the amount of pressure ascertained by the use of a *voltmeter*.

5. Amperage.—In place of the term *quantity*, or *rate of flow*, when speaking of an electric current, it is common usage to employ the terms *amperage*, *strength*, or *intensity*. As a unit, we employ the *ampere*, and find the amperage of any current by means of an *ampere meter*, or, as usually abbreviated, an *ammeter*.

6. The Watt.—That amount of energy of which any electric current is in possession, depends on the product of its amperes and volts. The unit of electric power is the *watt* and is 1 volt × 1 ampere; 746 watts constituting 1 horsepower. For instance, a current may have a pressure of 10 volts and a strength of 5 amperes; then its power is $10 \times 5 = 50$ watts. The voltage and amperage may be varied infinitely, but as long as the product of the two remains constant, the power is the same. Thus, a current of 500 volts and .1 ampere is of the same power as one with .2-volt pressure and 250 amperes strength. In both cases the product is 50 watts.

7. Resistance.—A current of water flowing through a tube is subject to a loss of pressure by reason of the friction between the fluid and the walls of the tube. It may, therefore, reach the end of the tube with only a small fraction of the pressure that it originally possessed. An electric current is also subject to such resistance when passing through a conductor, and will lose more or less in pressure, depending on the nature and dimensions of the conductor.

8. The Ohm.—The amount of electric resistance by which a conductor obstructs the passage of an electric current is expressed in *ohms*, which is the unit of resistance. The more ohms resistance a conductor possesses, the more extra or surplus pressure the current must have in order to reach the end of the conductor with a sufficient voltage to do the work required of it. All conductors offer *some* resistance, but when the same are short and of large diameter, the resistance may be so small as not to require consideration, while, on the other hand, when the conductor is long and of small diameter, as in an induction-coil, the loss may be very great.

9. Loss in Voltage.—The loss in voltage that an electric current suffers when overcoming resistance is usually transformed into heat, and if this heat is excessive, it may carbonize the insulating covering of the conductor, or it may even rise to such a height as to melt the conductor.

10. Positive and Negative.—A distinction is made in the direction in which the current is flowing. When the current is flowing *out* of a conductor, it is said to flow in a positive direction, and the end from which it issues is called the *positive terminal*, or *pole*. When flowing *into* a conductor, it is going in a *negative* direction and that end of the conductor is the *negative terminal* or *pole*. These distinctions hold true whether cells, dynamos, induction-coils, or static machines are considered. In these sources of electric energy, those parts from which the current emerges are always called the *positive* terminals, binding-posts, or poles, whatever term applies to the apparatus in question. The other terminal, then, is *negative*.

11. Anode and Cathode.—When considering apparatus in which an electrolytic action takes place, or when the current is sent through a vacuum tube, it is customary to term the positive pole an *anode*, and the negative, a *cathode*.

12. Direct and Alternating.—So far we have supposed that the electric current was continuously flowing in the same direction. This is not always the case; it may be that it periodically changes its direction in the same manner as a pendulum, oscillating backwards and forwards. A current of this nature is called *alternating*, while one that does not change its direction is termed a *direct* current.

13. Connections.—If an electrical device is to be connected with a source of electric energy, such as an induction-coil with a storage-battery, the *positive* terminal of the source is connected with the *negative* terminal of the device in which the energy is to be utilized, so that the current passes *from* the source *into* the receptive device and then again *from* the latter *into* the negative terminal of the former.

SIMPLE VOLTAIC CELL.

14. Parts of a Voltaic Cell.—We may, in a general way, speak of the sources of electric energy as sources of electric pressure. Whenever an electric pressure has been produced, a current will flow, if it is given a free path, and the strength of the current will be governed by the resistance it finds in its path or circuit. As an elementary example of such sources of pressure we may take the fundamental *voltaic cell.*

It consists, as illustrated in Fig. 1, essentially of a vessel *A* containing saline or acidulated water, in which are submerged two plates of dissimilar metals *C* and *Z*, or one metal and a metalloid.

The two dissimilar metals, when spoken of separately, are called *voltaic elements;* when taken collectively they are known as a *voltaic couple.* An *electrolyte* is a compound chemical substance in solution, and which undergoes decomposition when traversed by an electric current. A *voltaic battery* is a number of simple voltaic cells properly joined together. The *terminals* of a cell are the parts of the plates outside of the electrolyte.

It should be remembered that the polarity of that end of the plate or voltaic element that is acted upon by the electrolyte is always of opposite sign to its terminal. For instance, in the case of the zinc-and-copper couple illustrated in Fig. 1, the terminal of the zinc plate *Z*, or that part outside the electrolyte, would be spoken of as the *negative* terminal, while that part of the copper plate *C* outside the electrolyte would be spoken of as the *positive* terminal. When mention is made of the positive or negative pole of a cell, reference is always had to the exposed part of the elements, and no attention is paid to the submerged parts. The symbols + and − refer to the parts of the elements not contained in the electrolyte, and are always of the opposite sign to the parts submerged in the electrolyte.

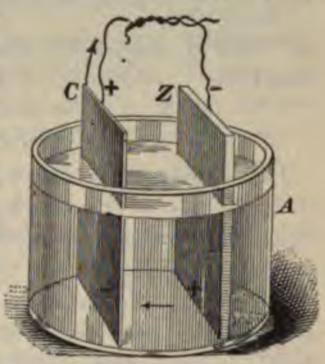

FIG. 1.

15. Chemical Action Occurring in a Simple Cell. As soon as exterior connection, by means of a wire, is made between the two plates, the plate of zinc *Z* is attacked by the acid and a part of it dissolved into a salt of that metal called *sulfate of zinc*. Large quantities of hydrogen gas are liberated around the copper and come to the surface at that point. The chemical energy liberated by the zinc is transformed into electrical energy, with the result that a difference of electric pressure or potential is created between the two plates. This difference causes an electric current to flow from *C* to *Z* through the wire in a direction corresponding to that of the arrow. A removal of the wires will interrupt the current, but the pressure will still exist, ready to continue the current as soon as the opportunity offers itself.

16. Ohm's Law.—The amount of current that a cell is able to furnish depends on its pressure, or E. M. F., and the resistance of the circuit. That is to say, the current is directly proportional to the E. M. F. and inversely to the resistance of the circuit. Arranging these relations in the form of an equation, we have the fundamental *Ohm's* law, which is: current $= \frac{\text{E. M. F.}}{\text{Resistance}}$. Usually this is abbreviated to the form: $C = \frac{E}{R}$, in which C stands for current, E for E. M. F., and R for resistance.

COMBINATIONS OF CELLS.

17. Main Principles.—Whenever the voltage or amperage of an electric source, such as a voltaic cell, is insufficient, a combination of several such cells may be made either for the purpose of increasing the voltage, or the amperage, or both.

Let us take an example from every-day life to make such a combination more easily understood. Suppose we have a long ladder leaning against the side of a high building, and that on this ladder are situated about 20 men that are engaged in passing a bucket filled with water, from hand to hand, until it reaches the top, where it is emptied into a pipe reaching down into the cellar. When this tube is full and maintained so, the column of water that it contains will evidently be in possession of a high pressure at its base, so that a motor situated in the cellar may be operated by it. In this instance we have 1 bucket on which each man in succession expends a certain amount of power, each adding gradually to the amount of potential energy of which it is in possession, until it reaches the top and has received its maximum energy.

Now, let the men descend and place themselves side by side in one row and let each one be provided with a bucket that he is required to fill from a large tank, to lift shoulder high, and empty into a common trough. From the latter the water flows toward a small waterwheel, which is set in rotation. In this combination we have 20 buckets lifted to the same height and contributing to *one* stream, while in the first instance 1 bucket is lifted to a height 20 times greater and only delivering a quantity of water corresponding to that of 1 bucket. These two arrangements are not the only ones possible, a combination of the two may be effected in many variations, such as 4 men high in 5 rows or 10 men high in 2 rows, etc., in either case varying the final pressure and rate of flow.

Having familiarized ourselves with these preliminaries, we can now easily understand the effect produced when voltaic cells or other electric sources are arranged in various combinations.

18. Cells in Series.—Let Fig. 2 represent 4 voltaic cells in which *a* are positive and *b* negative terminals. If, now, the cells are connected by means of short wires *c* in the manner indicated, it is clear that the current from cell c_4, say 2 amperes, will pass in succession through each of the cells c_3, c_2, and c_1, similar to the one pail of water lifted in succession by 20 men. The quantity of water remained the same, but an increase in energy was supplied by each man. We have here the current remaining of the same strength, being that of the one cell c_4; but each cell emits the current with its own pressure, that of 2 volts, added to it. The current will, therefore, leave the cell c_1 with 4 times the pressure it had in cell c_4, or 8 volts, but it will show no increase in strength or amperage. When cells are arranged in this manner, they are said to be arranged in *series*.

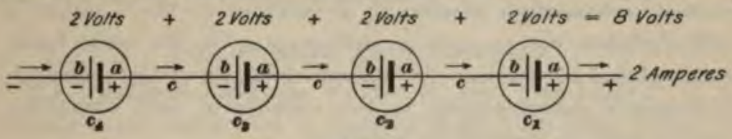

FIG. 2.

19. Cells in Parallel.—Now let the cells be arranged so as to correspond with the combination when all the men were standing side by side in one row, each provided with a bucket. This is shown in Fig. 3. Here all the positive poles *a* are united by the connectors c_1 to a common conductor *d*. All four cells are now sending their individual

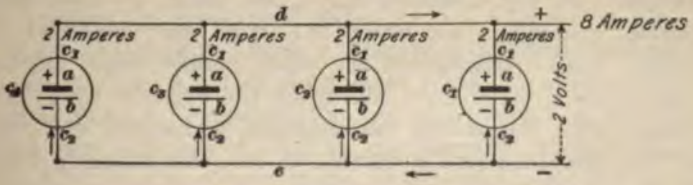

FIG. 3.

currents of 2 amperes to *d*, where they are united into a current 4 times the strength or amperage of each cell, but only with the voltage of one cell, or 2 volts. The current returns to the cells through conductor *e* and connectors c_2. When thus combined they are in *parallel* or *multiple*.

20. Difference Between Combinations in Series and Parallel.—Arranging the cells in *series* we have the current increased in *pressure* in proportion to the number of cells included, but no gain in amperage. On the other hand, when placed in parallel, the current strength, or the *amperage*, is increased corresponding to the number of cells combined, but no gain in pressure is obtained.

21. Combination of Series and Parallel.—By combining the two arrangements, as in Fig. 4, we may obtain an increase in both amperage and voltage, depending on the number of cells included and the manner in which they are arranged. In Fig. 4, cells c_1 and c_3 are placed in *series* and, likewise, c_2 and c_4, and these two rows are combined in *parallel*. Such combinations are called *parallel series*. Either of the series c_1, c_3 or c_2, c_4 multiplies the pressure by 2, producing 4 volts, but leaving the amperage unchanged, while the two rows combined send a current of twice the strength of one cell or 4 amperes, through conductor *d*. In all the figures, + and — signs indicate the polarities, and arrows, the directions of the currents.

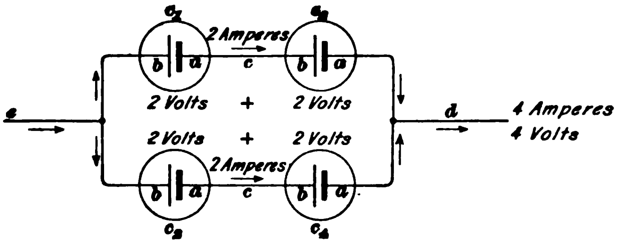

FIG. 4.

22. Ampere-Hours.—When reference is made to *ampere-hours*, it is to be understood as meaning the number of hours that a voltaic or storage cell will deliver a current of a certain amperage, which, again, will depend on its capacity. For instance, 100 ampere-hours may mean 1 ampere for 100 hours, 2 amperes for 50 hours, 4 amperes for 25 hours, and so on. How much the amperage may be increased beyond this will depend on the construction of the cell or accumulator. Some may safely deliver a much heavier current, while others may not, and would be ruined in so doing.

COMMERCIAL VOLTAIC CELLS.

23. Edison-Lalande Cell.—If the manipulator of a Roentgen ray apparatus is situated away from large cities, in a place where the electric current cannot be furnished from a central station, he may be obliged to fall back on those sources of electrical energy that formerly were used almost exclusively, that is, on the voltaic cells. Some of these offer less convenience than others, but they all suffer from the same fault, that of being comparatively expensive in their maintenance and more or less troublesome. There are few among the various varieties of primary or voltaic cells that are suitable for the heavier work of supplying the necessary current for an induction-coil. Among these may be mentioned first, as one of the most efficient, the *Edison-Lalande* cell. This is made up of a plate of cupric oxid held in copper frames enclosing the edges of the plates. The positive element of the cell is zinc, and the electrolyte a solution of potassium hydrate, or caustic potash. Two plates of zinc are used in most forms of this cell, one on each side of the cupric-oxid plate.

A cell of this type, having a capacity of 150 ampere-hours, is shown in Fig. 5. The cupric-oxid plate C is suspended in a copper frame F, F between the two zinc plates Z, Z, which are hung from each side of a lug on the porcelain cover of the jar. The sides of the copper frame of the oxid plate are carried through the cover supporting the plate, and form terminals B, B, either of which may be used as the positive terminal of the cell. That part of the copper frame which projects above the plate C is protected from the action of the liquid by tubes of insulating material T, T. A binding-post B_1, on the bolt that supports the two zinc plates, serves as the negative terminal. A layer of heavy paraffin oil is used in this cell to prevent the action of the air on the solution, and also to prevent the solution from creeping up the zinc plates.

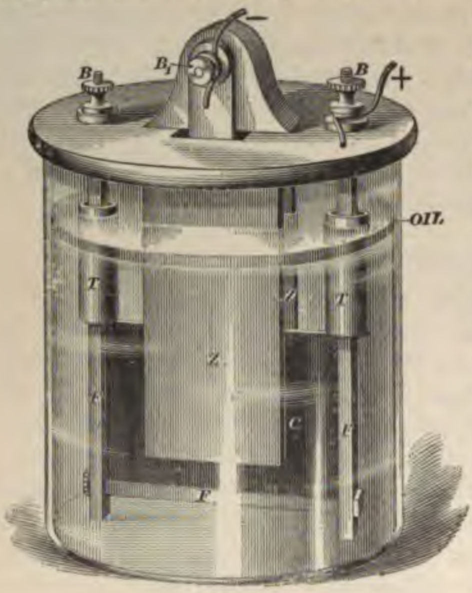

FIG. 5.

The 150-ampere-hour cell, shown in Fig. 5, will give a current of 3 amperes at a pressure of about .7 volt for 50 hours, with one "charge" of zinc, caustic potash, and oxid. They are very constant and are able to furnish a large current. Larger sizes will furnish the same current at the same pressure for 100 or 150 hours, respectively. They may deliver 6 amperes, if necessary.

24. The Harrison Cell.—Another cell capable of a large current is the *Harrison cell*. Its positive element is granulated zinc in an electrolyte of dilute sulfuric acid. The negative element is surrounded by a peroxid of lead. The voltage is 2.7 and the internal resistance 1 ohm. The capacity of the No. 3 cell is 300 ampere-hours.

25. The Grenet Cell.—Still another cell, which may be used, is the *bichromate*, or *Grenet* cell. This cell will not work as long before it needs recharging, but will demand this after a continued service of 2 hours, if it furnishes the current for an 8-inch coil.

This cell may either be arranged in single units and connected in series, or it may be made into the form of a *plunge-battery*, when all the elements are fastened to one common bar, which will simultaneously lift them out of the electrolyte when the battery is to be put out of action.

Fig. 6 shows the familiar type of the Grenet cell. It consists of a bottle-shaped jar with a hard-rubber or porcelain cover, from which two flat carbon plates *C*, *C* are suspended parallel to, and a short distance from, each other. Between them hangs a zinc plate *Z*, supported by a sliding rod *R*, that may be drawn up until the zinc is entirely out of the liquid. This rod is held in any position by the thumbscrew *T*. On top of the brass rod is a binding-post B_1, the other terminal of the cell being the binding-post *B*, which is connected to the two carbon plates *C*, *C*. The electrolyte is composed of 3 parts of potassium bichromate dissolved in 18 parts of water to which is added 4 parts of sulfuric acid. The E. M. F. of the cell is 1.92 to 2 volts.

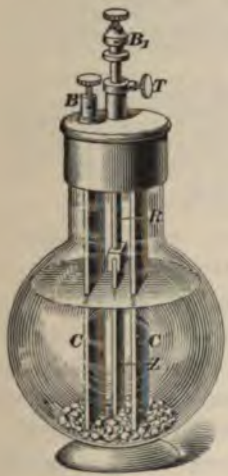

FIG. 6.

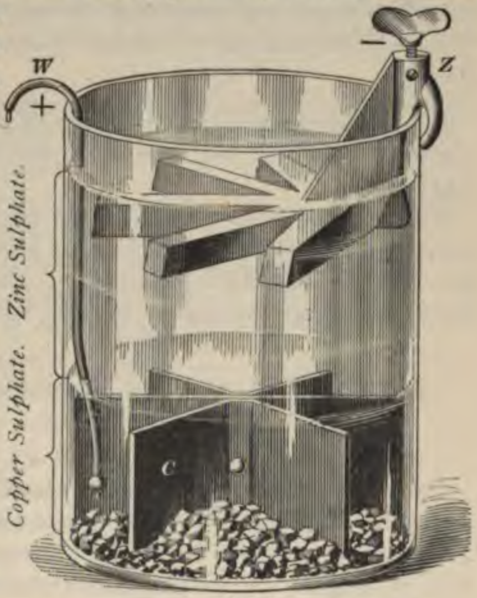

FIG. 7.

26. The Gravity Cell.—Another form of cell that is quite useful, is the so-called *gravity*, or *crowfoot*, cell, illustrated in Fig. 7. The zinc *Z*, from the shape of which the cell has received its name, hangs from the edge of the glass jar; the copper *C* is connected to the external circuit by the wire *W*, which is covered with an insulating material on those parts submerged in the liquid. When the cell is set up, the copper plate is surrounded with crystals of cupric sulfate until it is completely covered. The zinc weighs about 3 pounds, and 2 pounds of cupric-sulfate crystals are required to charge the cell. The E. M. F. is about 1.07 volts. The maintenance of this cell is simple.

27. Bunsen Cells.—Bunsen cells have also been used for operating coils, but they are rather objectionable on account of their odor.

Voltaic cells are at present rarely used for heavy work, but rather more for charging accumulator, or storage-batteries. They can then do their work more slowly, without being strained to their utmost capacity, and at a higher efficiency.

ACCUMULATORS, OR STORAGE-BATTERIES.

CLASSES.

28. Difference Between Primary Cells and Accumulators.—There is this difference between a primary and a storage, also called a secondary, battery, that while the first is able to furnish an electric current primarily as a result of chemical action taking place in the battery, the storage-battery, on the other hand, must first have a chemical action produced in it by means of an outside electric current. After this action has been completed, the source of electrical supply is disconnected. The battery is now seeking to return to its original chemical condition, and will, in doing so, return the greater part of the current that was sent into it and caused said chemical decomposition. We see, then, that it is not electrical but chemical energy that is stored in the battery, and that it is this energy that is changed into electrical energy.

An advantage of the storage-battery over the primary battery is that in the former the rate of this transformation can be varied within wide limits and heavy currents furnished for short lengths of time that would be far beyond the capacity of a primary battery of the same size.

Whenever it is possible to have storage-batteries conveniently charged, they are to be preferred to primary batteries for the purpose of operating an induction-coil.

In case an incandescent-lamp circuit is not available for charging storage-batteries, then a compromise must be made and some style of primary battery used for the purpose.

29. Chlorid Accumulator.—There are various classes of accumulators in the market of more or less efficiency, but, for Roentgen ray work, the *chlorid* accumulator has so far been used almost exclusively and has given very good satisfaction. It has the advantage over the older forms of the Planté and Fauré class that it will stand harder usage and give a heavier discharge without any liability to distortion or *buckling*. With ordinary care they will last for years.

The plates of this type of storage-cells are made as follows: A mixture of zinc chlorid and lead chlorid is melted and run into molds that form it into cylindrical pellets, or pastils. The pellets are placed in a second mold, and an alloy of lead and antimony is melted and forced between the pellets under heavy pressure. When this cools it forms a plate, binding together all the pellets of zinc and lead chlorid. After being given some supplementary treatment, the requisite number of plates are set up together

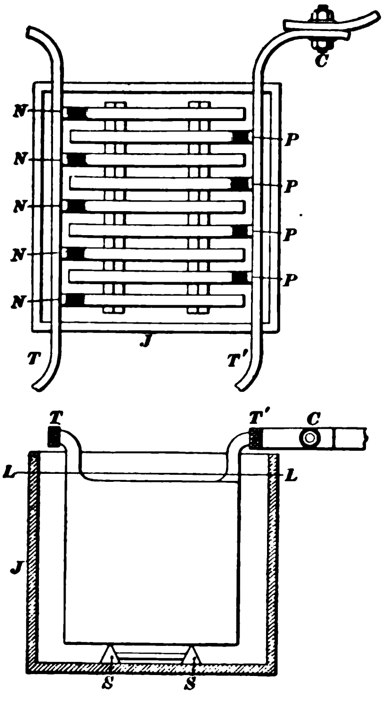

FIG. 8.

to form a cell, positive and negative alternating, and connected to common conductors as shown in Fig. 8, where the plates marked *N* are negative and those marked *P* are positive. The number of negative plates is always one more than the number of positive plates, so that *each* side of each positive plate has presented to it the surface of a negative. From a corner of each plate a lug projects; the lugs on the nagative plates are joined to a connecting strip, as represented at *T*, and the lugs on the positive plates are similarly joined to a connecting strip *T′*. These connecting strips are extended beyond the limits of the cell, and serve to connect the various cells of the battery together, as shown at *C*, the connection being made by a brass bolt, which firmly clamps the connecting strips together.

The plates are placed in the jar *J*, and they rest on a support made from two strips of wood (usually boiled in paraffin) of triangular section *S*, *S*. These support the plates at such a height that any loosened particles of active material fall below the level of the bottom of the plates, thus preventing possible short-circuiting. When in position, the electrolyte is poured in until it reaches the line *L L*, thus covering the plates. The plates are usually kept separate by blocks of insulating material.

These accumulators are classified under various types and the selection of the proper type depends on the work they will have to perform.

The following data regarding the type D_5 may be of interest. The normal charging rate of the same is 5 amperes; when discharging, it may do so in:

8 hours at the rate of 5 amperes = 40 ampere-hours.
5 hours at the rate of 7 amperes = 35 ampere-hours.
3 hours at the rate of 10 amperes = 30 ampere-hours.

Of course, it may be discharged at any desirable rate below 5 amperes, when its ampere-hours will be correspondingly increased. It is seen that by increasing the rate of discharge its total capacity is decreased. The charging current of these cells is about 1 ampere for each 12 square inches.

30. Charging Accumulators.—When an accumulator is connected with a source of electric energy, such as a voltaic battery, for the purpose of being charged, its *positive* terminal should be connected to the *positive* terminal of the battery. In charging 5 cells of this class by means of primary cells, 15 such as the Harrison type may be required, arranging them in groups of 3 in parallel and 5 of these groups in series. They would then be able to send a current of 4 amperes through same. It is supposed that the capacity of the latter is 40 ampere-hours. By adding 10 per cent. to this, making a total of 44 ampere-hours, we will find the time required for charging to be $\frac{44}{4} = 11$ hours. The capacity of these primary cells being 300 ampere-hours, they would be able to maintain a charging at this rate for about 225 hours.

As a further example of charging accumulators, let us suppose that the latter consists of 8 cells with a maximum voltage of 2.5 volts per cell. Total voltage will then be: $2.5 \times 8 = 20$ volts. If the cells be discharged down to 1.8 volts per cell, below which point the discharge should not continue, then the minimum voltage would be $1.8 \times 8 = 14.4$ volts.

31. Counter Electromotive Force.—The E. M. F. of the accumulator when acting in opposition to that of the charging current is called a *counter* E. M. F. In this instance, the counter E. M. F. is 14.4 volts at beginning of charge, increasing to 20 when the charge is completed. The internal resistance of these cells being low, the charging cells should also be so and with a high E. M. F.

32. Examples of Charging.—For charging purposes we may also select those of the *gravity* class, of which many good varieties are in the market, or *bichromate* cells. Utilizing the latter, in which each cell has an E. M. F. of 1.5 volts and .06-ohm resistance, and taking 14 cells, the total E. M. F. would be $14 \times 1.5 = 21$ volts, with an internal resistance of $14 \times .06 = .84$ ohm. Letting the total resistance of the primary and storage cells amount to 1 ohm, we would, if all the cells were placed in series, have a current at starting, as follows:

$$C = \frac{21 - 14.4}{1} = 6.6 \text{ amperes.}$$

When the work of charging is nearly completed the current will be

$$C = \frac{21 - 20}{1} = 1 \text{ ampere.}$$

Estimating the average charging current to be 3.5 amperes and the ampere-hours at 180, and adding 10 per cent. to the latter, we find the time required to be $\frac{198}{3.5} = 62$ hours.

By increasing the number of cells to 25, their total voltage would be $25 \times 1.5 = 37.5$, and the average current-strength 12.25 amperes. The charging would now be complete in about 15 hours.

33. Gassing.—When the charging is complete, the hydrogen and oxygen gases, which are developed by the current, can no longer be taken up and chemically combined with the plates. They will therefore escape; the so-called "gassing" takes place and the water assumes a milky appearance. Continuing the charging current beyond this point, that is, overcharging the cells, does no harm to the plates, but the energy represented by the current is wasted.

It is important not to increase the charging rate beyond that recommended by the manufacturer, otherwise the developed gas would not have time to unite with the positive and negative elements, and "gassing" would occur before the cells were fully charged. This would cause a waste in electric energy with possible injury to the cells.

34. Discharge.—When the charging current is discontinued and the external circuit of the cell completed by means of conducting-wires through some electrical device, then a current will flow in the *opposite* direction to that of the charging current, the pole that was connected to the positive pole of the primary battery now acting as a positive pole. If there should be any uncertainty as to which is the positive pole of the primary or storage-battery, then it can at once be determined by dipping the ends in water slightly acidulated, without letting the ends touch each other. The water will then be decomposed, and the increased amount of hydrogen gas developed at the negative pole will at once mark the latter as such. The positive and negative pole of a storage-battery should never be connected directly without some intervening resistance. The rate of discharge would otherwise be so heavy as to perhaps permanently injure the battery.

35. Testing of Accumulators.—In case the discharge current from an accumulator does not show the usual strength, one of the cells may have had its connections broken or a "buckling" may have occurred. A 2-volt incandescent lamp provided with conducting-wires may then in turn be connected to the terminals of each cell, and its condition ascertained by the glow of the lamp. Should no glow take place at one of the cells, then this one should be disconnected and the trouble ascertained. The total voltage of a battery may also be found by connecting a lamp to its main terminals possessing a voltage corresponding to that found by multiplying the total number of cells by 2.

36. Other Methods of Charging.—We have here mentioned only the one combination of placing the accumulator cells in series, as this is the simplest and quickest method to pursue. There may be conditions in which it is not possible to supply the high voltage required in the above example. In that case each cell may be charged separately or in combinations of 2 or 3, as the case may be. Or, if a charging current can be obtained of low voltage, but of high amperage, then all of the accumulator cells may be placed in parallel. Supposing the available amperage to be about 98, then it would take about the same time for charging as in the example cited above, when all the cells were in series, that is, in about 15 hours.

If a small dynamo is utilized for the purpose, then it is preferable to have one that is shunt-wound. This would prevent a reversal of its polarity by a possible slowing down in speed, in which case the current would return from the cells.

In Germany, Gulcher's *thermo-batteries* have been used with some success; they are durable and practical, though unable to give a high voltage and amperage, but they may, nevertheless, be useful for slowly charging storage-batteries. The largest single battery gives a current of 3 amperes with 5 volts pressure, and has an internal resistance of .65 ohm. Illuminating gas required for heating amounts to 6 cubic feet per hour. They have this advantage, that after lighting the gas-burners they are at once ready for use, require no attention, and may be left unused for months without loss in efficiency from deterioration.

37. Edison's Storage-Battery.—Lately, Edison has manufactured a storage-battery that is claimed to be far superior to any other existing at present. Of the advantages claimed, the following may be mentioned:

1. Absence of deterioration by work.
2. Large storage capacity per unit of mass.
3. Capacity of being rapidly charged and discharged.
4. Capacity of withstanding careless treatment.
5. Inexpensiveness.

The negative pole is attached to an element consisting of a finely divided compound of iron with an equal volume of graphite flakes, and the positive to one consisting of superoxid of nickel; it may therefore be called a nickel-iron cell. The electrolyte is potash, preferably a 20-per-cent. solution of potassium hydroxid, the freezing temperature of which is 20° below zero, Fahrenheit.

The initial voltage of discharge is 1.5 volts, while the mean voltage of full discharge is approximately 1.1 volts. The normal charging current rate is about 8.64 amperes per square foot. Charging and discharging rates are alike and may be 3½ or only 1 hour without any apparent detriment.

The positive and negative plates are mechanically alike, and consist of a thin sheet of steel in which rectangular holes are stamped. Each hole or opening is filled with a pocket or shallow box containing the active material; the box is perforated with numerous small holes to admit the electrolyte, but conceals entirely the contained active material from view. The cell may be fully discharged to the practical zero point of E. M. F. without detriment.

INCANDESCENT-LAMP CIRCUITS.

REGULATION OF CHARGING CURRENT.

38. Incandescent Lamps.—When connection can be had with an incandescent-lamp circuit, then this should always be utilized in charging accumulators, as it is not only much more convenient, but also more economical. As the amperage of this current would be very heavy for charging purposes, some resistance must be inserted in the circuit to reduce the current to its proper strength. For this purpose, metallic wires of varying lengths and diameters, constituting a so-called rheostat, may be used; but, ordinarily, it is more convenient to let the current pass through a certain number of incandescent lamps and in this manner provide the necessary current-strength.

A 16-candle-power incandescent lamp will pass a current of .5 ampere, and a 32-candlepower lamp, 1 ampere. By varying a number of these lamps in parallel, any required amperage may be obtained for charging purposes.

39. Connections.—Fig. 9 gives a diagrammatic view of how lamps and accumulators may be arranged. *a* and *b* are

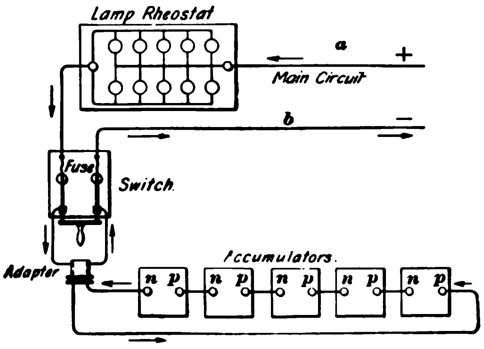

FIG. 9.

the main wires of the lamp circuit, and the arrows indicate the direction of the current through the lamps, switch, adapter, and accumulators, back through conductor *b* into the main circuit. If 16-candlepower lamps are selected, then 10 of these will allow a current of 5 amperes to pass through the accumulators when the latter are arranged in series. The adapter is a plug-like appliance that may be inserted in a stationary socket and simultaneously connects the positive and negative wires of the accumulators to those of the main circuit. Two fuses are installed on the switch to insure against an excess of current, in which case they will burn out and break the circuit. The accumulator should first be, respectively, connected and disconnected before the switch is closed or opened. To give a detailed description of how to manage storage-batteries would be unnecessary, as the makers always supply this information. It should be added that, in general, there would be no necessity in using storage-batteries for operating the induction-coil when an incandescent-lamp circuit is installed in the operating-room, though some operators prefer even then to use storage-batteries, claiming to obtain better results. Ordinarily this would only be necessary if the coil had to be operated some distance away, where nothing but storage-batteries could be utilized.

40. Rheostat.—When using the incandescent-lamp current for operating the coil, some means must be had for regulating the current-strength similar to those used when charging storage-batteries. Preferably a variable resistance, made up of various lengths of iron or German silver-wire, is then resorted to. These are combined either in a box or plate, over which a lever may be moved from one position into another so as to include shorter or greater lengths of these wires, thus interposing a lesser or greater resistance in the circuit. The reduction in pressure that the current suffers by passing through such resistances is rather wasteful when the pressure is that of the ordinary lamp circuit. All pressure not wanted in the coil is then wasted in the form of heat in the resistance-box. Resource is, therefore, often had to other means for bringing on the reduction in pressure without so much loss. As such, the motor-generator has been found very serviceable.

MOTOR-GENERATOR.

41. Construction.—The motor-generator is a combination of a motor and a dynamo in one frame with one set of field-magnets and two armatures. One of the latter is used as a motor, and sets the other armature in rotation, generating an E. M. F. of its own entirely independent of that in the main circuit and constituting part of a separate circuit. By selecting the proper size of wire and coils for the latter armature, it is possible to have a current of any desired pressure in the latter circuit. Thus the pressure of 100 volts in the lamp circuit may be changed in the generator to 10 volts with an efficiency of 80 to 90 per cent., consequently without the loss in heat, as in the rheostat. This is not the only advantage that a motor-generator may possess. It may also take an alternating current, which is not suitable for operating induction-coils, and change it into a direct current, the alternating current operating the motor-armature and the direct current emanating from the generator-armature.

GENERATORS.

42. Method of Operation.—In localities where no connection can be made with commercial lighting circuits, it may be possible to have a small independent generator of about $\frac{1}{3}$ horsepower that may be operated by a water-motor, if a pressure of at least 10 pounds is present in the water-mains. For the utilization of the existing water-power, the Pelton water-wheel is superior to any other motor. If, for instance, a water pressure of about 40 pounds is available, which is usually the case, then a motor of 6 inches in diameter will furnish $\frac{1}{2}$ horsepower. This motor may be situated in the cellar and be directly connected to a small dynamo from which the current may be sent through the induction-coil. Or, the dynamo may be used for charging a number of accumulators, which will be available at any time for operating the coil. In case water pressure should not be at hand, then a small gas or gasoline engine may be installed and its power utilized in running a $\frac{1}{3}$-horsepower dynamo. The current furnished by the latter may be sent directly through the induction-coil, or, by winding the dynamo for low voltage, it may charge 4 or 5 storage-cells and these be used with the induction-coil. Dynamos and engines constructed with this purpose in view are in the market and may be had with the necessary directions for their installation.

STATIC MACHINES.

MAIN PRINCIPLES.

43. Comparison With Other Sources of E. M. F. The *static machine* has the advantage over the other sources of electrical energy that it contains the whole Roentgen ray apparatus, so to speak, combined in one unit. No primary or storage-batteries, nor transformer, induction-coil, or rheostat are required. All that is necessary is to set the machine in operation and a current of the required voltage and amperage will be delivered to the Roentgen ray tube. Considered from this standpoint alone, it is superior to all other means used for the same purpose. Nevertheless, these advantages, which seem to make it so greatly superior, are counterbalanced by certain drawbacks. The first of these is the price, which certainly is much higher than that of a coil able to produce the same results. Then the room required for its installation, and at times a certain dependency on the condition of the air, whether rich in humidity or not, must also be considered. The increase in price would not be against it in cases where the static currents are used for general therapeutic purposes, as its field of usefulness there is very great, while that of the induction-coil would be nil. On the other side, it has been claimed that the results obtained by the static machine in Roentgen ray work is inferior to that produced by means of the induction-coil, the current-strength of the latter being greater, and the time required for the production of good skiagraphs, as a consequence, materially reduced.

Weighing both sides of the question, we think it may safely be said, that when the intention is to have an apparatus for Roentgen ray work alone, an induction-coil is preferable. If the practitioner wishes also to use his apparatus in general electro-therapeutic work, then a static machine is preferable, and also in localities where it is difficult to obtain the commercial lighting current or to have necessary repairs attended to. The static machine is not liable to breakdowns and may run for years without any more attention than that of an occasional general dusting and cleaning.

44. Methods of Operation.—The machine may be operated by hand, or, if the power is to be supplied for long periods, by means of a small motor, either an electric, a hot-air, a gasoline engine, or with the small water-motor already mentioned, when the suitable water-power is at hand.

It will be out of place here to enter into an extended description of the static machine. Those that wish to study the principles on which the same is based may find these fully explained in *Electrostatics.* It may be said to consist of a series of stationary and revolving glass plates, the latter carrying positive and negative charges back and forth between the former, increasing the potential of the charges they deposit on them at the same time as free positive and negative charges are induced on the exterior metal conductors, called prime conductors, whence they may be delivered to the apparatus where they are to be utilized.

An increase of the number of plates will give a corresponding increase in the current-strength. Machines with glass plates too small in diameter or too few in number will not be satisfactory. They should at least contain 6 to 8 revolving plates 24 to 30 inches in diameter.

As it is of importance that the positive pole of the static machine be connected to the anode of the tube, one must be able to make a distinction between the two poles while observing the spark-discharge. On bringing the sliding rods so near together that the spark-gap is about 1 to 2 inches, it will be noticed that the stream appears white near the positive and violet at the negative pole. Should this test not seem decisive enough, then one of the prime conductors may be grounded by connecting it to a gas-pipe or water-pipe, when the spark-discharge will cease if the positive pole is grounded, but will be undisturbed when the negative pole is so connected. It should be remembered that while the prime conductors of a static machine may retain the same polarity for a long time, they are liable to change. Should such a change have occurred, it will at once be noticed by the peculiar glow of the tube. The green fluorescence will then appear, not in front of the anode, but will seem to emanate from its rear. The machine should be stopped at once and the tube connections reversed.

A static machine, to be at its best in skiagraphic work, requires tubes that are constructed especially for such machines.

VARIOUS METHODS FOR OPERATING THE ROENTGEN RAY TUBE.

45. There are three methods by which the charges from the static machine may be sent through the vacuum tube:

1. The direct method.
2. The oscillating-current method.
3. Direct method with current interrupters.

46. The Direct Method.—When this method is used, the conducting-wires from the Roentgen ray tube are connected directly to the prime conductors of the static machine and the spark-gap adjusted in conformity with the vacuum of the tube. Should the tube not start at once, it is only necessary to bring the prime conductors near enough together to allow a spark to pass, when the tube generally will begin to glow.

47. The Oscillating Current Method.—In this combination, shown in Fig. 10, the induced charges of two Leyden jars are used for operating the tube. For this purpose, two Leyden jars of the smallest size are used, one for each prime conductor and directly connected with them. In the binding-posts, connected with the outside coatings of the jars, the conductors from the tube are inserted. It must here be remembered that the outside coating of the jar connected with the positive prime conductor is not positive, but negative, and vice versa with the negative prime conductor.

Adjust the sparking-distance between the prime conductors from 3 to 6 inches, after the machine is in full action, until the position is found producing maximum radiance. Unless the jars are very small, there is always some danger of having the charges from the latter puncture the tubes.

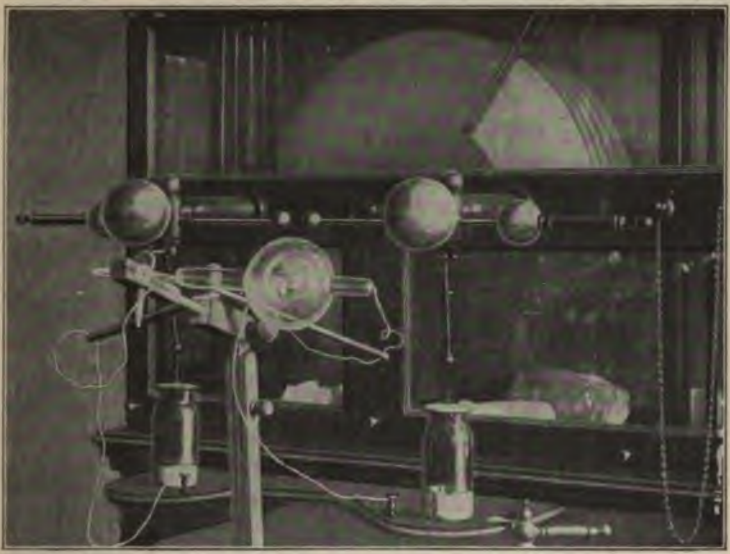

FIG. 10.

48. Direct Method With Current Interrupters. This is the method that is mostly used with static machines and that seems to give the best results. A little instrument, called an **interrupter,** is fastened to the insulating handle of each of the sliding rods, so that the little ball of the interrupter is in contact with that of the sliding rods, as seen in Fig. 11. The tube conducting-wires are inserted in little eyelets with which each of the interrupters is provided. The machine is set in action and the sliding rods of the prime conductors are separated so that no spark will pass between them. The length of the gaps between the interrupters and sliding rods should be adjusted until the tube gives maximum radiance.

It is usually found that it is sufficient to have a spark-gap only at one of these interrupters. Which one of these to select depends on the vacuum of the tube. If the vacuum is high, then the spark-gap at the negative interrupter seems to give the best results; if low, either the positive or negative, or both, may be used. Sometimes it may not be necessary to use either of the interrupters.

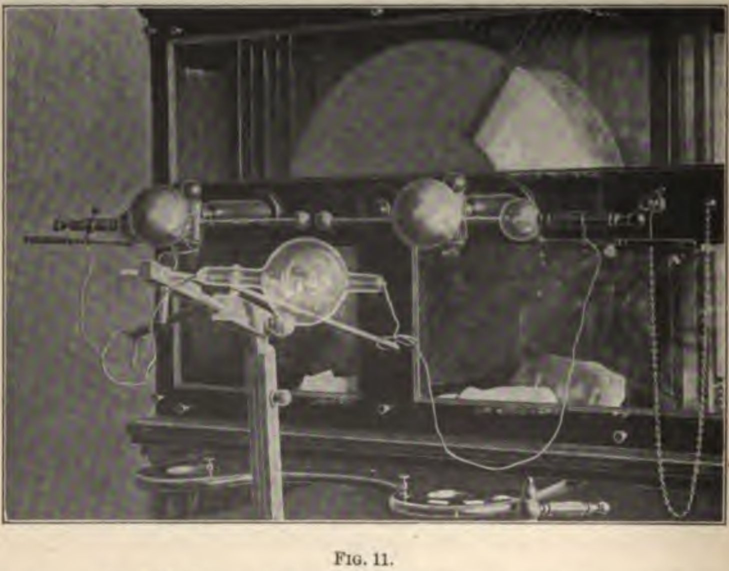

FIG. 11.

TRANSFORMERS.

THE INDUCTION-COIL.

49. Induction.—There are other means by which an E. M. F. may be produced than by the transformation of chemical into electrical energy. The most important of these is *induction*. Induction means the production of magnetization or electrification in a body without actual contact. We have seen that in order to make a current flow in a conductor it was necessary that the same was in actual contact with the source of electrical energy, for instance, a primary battery. When utilizing the phenomenon of induction, this is no longer necessary; we can then make a piece of iron magnetic by simply locating it in the neighborhood of a magnet or an active electric conductor. And, further, it is also possible to make a current flow in a conductor situated near another conductor carrying an electric current. *Why* these results are produced can here be explained only in general outlines. Full explanations will be found in *Magnetism and Electromagnetism.*

50. Inertia.—A current flowing along a conductor behaves as if in possession of *inertia.* By inertia is meant the tendency of a body to oppose motion while at rest, and while in motion to counteract a variation of same or a cessation altogether. We may find an analogy to this in the action of a grindstone, a flywheel, or any revolving body. To start a grindstone we must first overcome its inertia, its tendency to remain at rest. When in motion, and the intention is to stop it, its inertia will again assert itself, and it will tend to remain in motion; a counterforce must, therefore, be exerted to bring it to a standstill. Also, while in motion, it will oppose any variation in the speed of rotation.

51. Self-Induction.—An electric current will show similar characteristics. When a current is sent into a conductor there are forces active, tending to oppose the starting of the current. After the current is flowing, these same forces are counteracting any variation in current-strength, or its cessation. This reactive influence is called *self-induction*, and is one of the most important phenomena in electricity. At first glance it would seem to be a decided hindrance, but further study of the subject will show it to be of the most vital importance. The result of this self-induction is that when a current begins to flow, it cannot at once reach its full strength. After it has reached such strength, it will not at once submit to any change in it. And, further, when the current-supply is suddenly cut off, there comes an extra E. M. F. into play that tends to continue the current flow, entirely independent of the source of supply. This latter phase of self-induction is the only one used in Roentgen ray work.

52. Experiment Illustrating Self-Induction.—Let us now go a step further and imagine a conducting-wire to be divided in two parallel wires, entirely independent of each other, that is, insulated from each other along their whole length. We may still imagine these to be one wire, with this difference, that we are now able to send a current through one-half while the other is idle. Fig. 12 gives a diagrammatic view of the two conductors with their connections. The active conductor *b* is connected to two binding-posts b_1 and b_2. Conductor *d* connects the former to a key, or switch, *s*; the battery *B* is also connected to the latter and to the binding-post b_2 by conductors *e* and *f*, respectively. The idle conductor *a* is connected to two other binding-posts a_1 and a_2, and the latter is brought in communication with a galvanometer *G* by wires *c*, *c*.

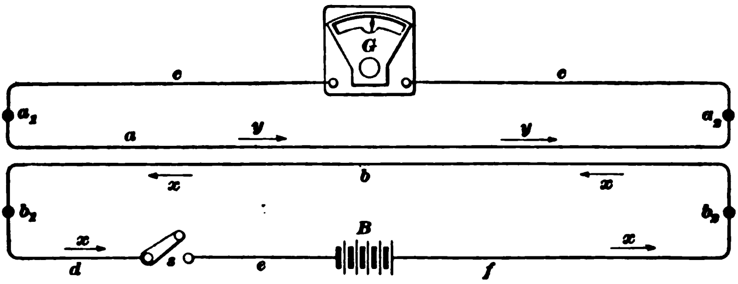

Fig. 12.

In order to fully understand the following experiment, let it again be emphasized that the wires *a*, *b* could be one wire, if it were possible to let one part of the wire be idle while the other transmits an electric current. The phenomenon of self-induction takes place just as well with one as with the two wires into which it is here divided.

When the key *s* is closed, a current will flow through the conductor *b* in the direction of arrows *x*, *x*. A self-induction will at once arise and tend to send a current in an opposite direction, thus weakening the closing current and delaying it in reaching its full strength. Simultaneously with the self-induction produced in *b* a similar induction will be called in play in conductor *a* in the direction of arrows *y*, without any actual contact between the two conductors. But there is this vital difference between the two phenomena, that while that in *b* must act against the pressure or, E. M. F., of a current, that in *a* has an entirely open field and can at once send a current through the whole circuit *a c*, signifying its presence by the motion of the pointer in galvanometer *G* toward the right.

As soon as the current in *b* has reached its full strength, then all reactive influences will cease both in this conductor and its mate. At any moment when any *increase* in current-strength takes place, the same results will follow, and at once a current will flow in conductor *a* in the same direction as arrows *y*.

53. Extra Current.—The most important part of this experiment is the result following the *opening* of key *s*. The self-induction of the circuit *b* will, then, again assert itself at once and will now tend to *maintain* the flow, producing what is called an *extra current*. While the key *s* is in the act of being opened, and thus breaking the continuity of the circuit, the only possibility for the current to continue its flow is to complete its circuit by jumping across the air-space in key *s*, which it will do by means of a spark. Again, a self-induction has asserted itself in the other circuit *a*, and here, also, in the same direction as that in *b*, that is, in the direction of the arrows *x*, consequently, in the *opposite* direction to the previously induced current, which was indicated by the arrows *y*. The pointer in the galvanometer will now go to the left.

54. Primary and Secondary Currents.—To repeat: on closing the key *s*, an E. M. F. will be produced and a current will flow in circuit *a* in the *opposite* direction to that of circuit *b*. On opening the key *s* an E. M. F. will be produced and a current will flow in the circuit *a* in the *same* direction as that in circuit *b*. The circuit *b* in which the inducing, or primary, current flows is called the *primary* circuit, while the circuit *a* conducting the induced, or secondary, current is called the *secondary* circuit.

55. Condenser.—It is seen, then, that the circuit *a* is active *only* when a change takes place in circuit *b*, and it will be understood that the more violent these changes are, the more violent will be the results in circuit *a*. To accomplish a sudden *starting* of a current in conductor *b* will not be possible, as the self-induction will always prevent it. The only means left is, therefore, to make the break at *s* as sudden as possible, and here some difficulties have to be overcome, that is, sparking at the contact points of key *s*. Fortunately, means have been found to overcome this by the appliance *c*, shown in Fig. 13,

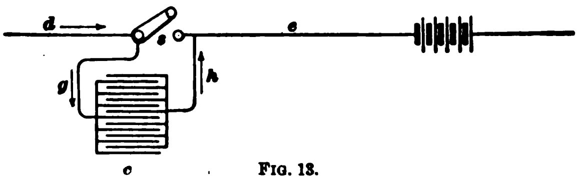

FIG. 13.

that consists of a number of tin-foil sheets, insulated from one another and alternately connected with the two conductors *g* and *h*. The latter are in electric connection with the lever and contact plate, respectively, of the key *s*. This combination is called a *condenser*, and is, in reality, two separate conductors of very large area, insulated from each other, but capable of exerting a mutual inductive influence on each other. The effect produced by inserting this condenser in parallel with the key *s* is, that when the latter is opened, the *extra* current from conductor *d* will, by preference, pass down along wire *g* into the condenser *c* instead of sparking across the air-gap in key *s*. By selecting a condenser of the right capacity, it is possible to make the current interruption practically instantaneous and to produce a maximum effect of self-induction in the circuit.

56. Principles of the Induction-Coil.—The experiment, previously described, elucidates the main principle on which the induction-coil is based, and it remains only to show the practical application of it.

The first requirement will be to shape the wire *b*, Fig. 12, into the form of a helix, partly because its various coils and layers have a stronger mutual inductive influence on one another, and also to economize space, as one single straight wire would show very feeble inductive effects when transmitting a current of ordinary strength.

In Fig. 14, the conductor *b* of Fig. 12 has been transformed into the coil *P*, here called a *primary* coil, because transmitting the primary or inducing current from the battery. Instead of the key *s* we have now an automatic interrupter to be described further on. *C* is a core of soft iron usually made up of a number of soft, thin iron wires. The core is not made solid but subdivided, so as to prevent the induction from causing local currents to flow in the core, which would tend to heat it and also to cause a reaction on the current in the primary coil. The purpose of the core is to increase the self-induction of the coil. An active electric conductor shows magnetic effects in its immediate surroundings. These will be magnified when, as in this instance, numerous layers of wires surround an iron core; the latter will have magnetism induced in it and show very strong magnetic attraction. *R* is the condenser; it consists of insulated leaves *a* and *b* united, respectively, to the conductors a_2 and b_2 that are connected to the ends of the coil *P*.

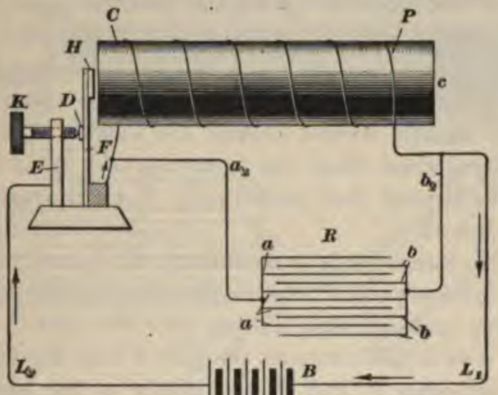

FIG. 14.

57. Action of an Induction-Coil.—The current from the battery passes through conductor L_1 into the post *E*, from here through the screw *K* to the contact *D* on armature *H* into the coil P. The core will be magnetized and attract the armature H. The continuity of the circuit has thus been broken at D, and a current can no longer pass across the air-gap between D and the screw K. As the coil is now cut off from all connection with the battery, the self-induction of the coil will begin to assert itself and send an *extra current* through the coil and conductor b_2 into the condenser. When this current has ceased, the magnetism of core C will, also, cease and the armature, or hammer, H will return to its original position, again letting the contact D come in touch with screw K. The current then continues its flow as before, and with the same results.

The other conductor a, as shown in Fig. 12, is also made into a coil and usually wound around the outside of the primary coil. It constitutes, then, the *secondary* coil of an induction-coil, and the current that periodically flows through it is the *secondary* current.

In Fig. 15, S represents a secondary coil wound on the outside of the primary coil P; both coils are supported by a spool O of insulating material surrounding the iron core C laid in its interior. A switch W connects the post E with the terminal P_1, and the terminals P_1 and P_2 are joined to the battery B by means of L_1 and L_2. The terminals S_1 and S_2 of the secondary coil are not, for the present, in electrical connection with each other; the secondary circuit is, therefore, open.

58. Importance of Quick Interruptions.—From the fact that a current in the secondary coil flows only when a change takes place in the primary coil, it follows, at once, that if any great activity is to be produced in the former coil, these variations must be as numerous and as great as possible; therefore, the importance of having a suitable and well-constructed interrupter, or vibrator, for which reason we will further on explain this device in detail.

59. Nature of Secondary Current.—The next question that will suggest itself is this: "How can the current from the secondary coil be used for the lighting of a Roentgen ray tube, when the latter demands a direct current." As already explained, the self-induction caused by the *breaking* or opening of a circuit is many times larger than that resulting from the *closing* or completing of a circuit. Consequently, the former will be able to pass a current through a resistance that the latter will be powerless to penetrate. We can therefore understand that if we have a spark-gap of, say, 10 inches between the terminals of the secondary coil, the breaking current might be able to jump across it, while the closing current will be unable to do so, because its E. M. F. is perhaps unable to bridge a gap longer than 6 inches. As a result of this, sparks will only pass across belonging to the breaking currents, and as all these go in the same direction, it follows that the current will be *unidirectional* and *intermittent*.

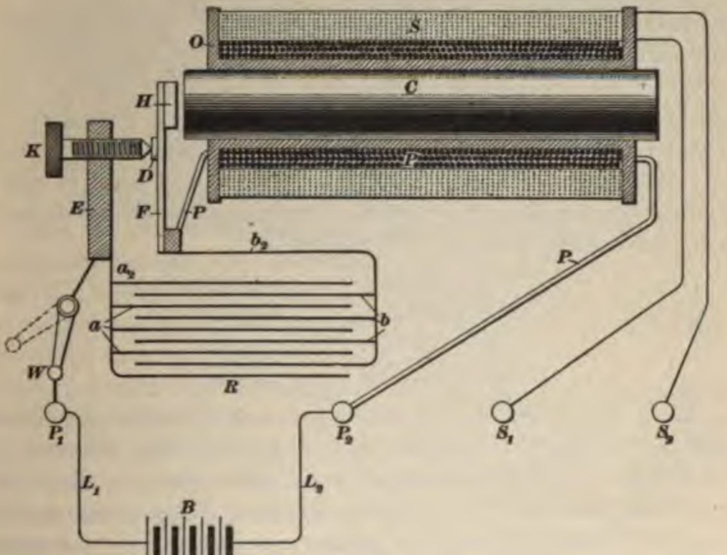

FIG. 15.

60. Difference Between E. M. F.'s in Primary and Secondary Coils.—Another point that may offer some difficulty in understanding is the relation between the pressures in the primary and secondary coils. If the coils *P* and *S*, Fig. 15, were made of wire of the same diameter and length, then the pressure and strength of the currents in both coils would practically be the same, not considering a certain loss depending on the efficiency of the combination. The more windings or convolutions that the secondary coil contains, the more will it be exposed to the effects of the inductive influences of the primary coil. The E. M. F. developed in the secondary coil would, up to a certain limit, increase in direct proportion to the increased number of windings that it may contain in the same space on the bobbin. But as the total power in watts developed in the secondary coil cannot be increased, it follows, as a consequence, that an increase in pressure can only be bought at the expense of a decrease in current-strength. For instance, let it be supposed that a power of 50 watts is developed in the secondary coil. This may be done by a current of

10 volts and 5.0 amperes.
100 volts and .5 ampere.
1,000 volts and .05 ampere.
10,000 volts and .005 ampere.

Thus, the pressure in the secondary may be increased to from 200,000 to 300,000 volts, but with a corresponding decrease in amperage. It is well to bear in mind, particularly in Roentgen ray work, that coils having a large sparking distance cannot give a strong current, unless the primary is traversed by a current much larger than that ordinarily used for Roentgen ray coils, and the secondary coil is made of a correspondingly heavier wire.

Increasing the diameter and decreasing the length of the wire in the secondary coil will decrease its voltage and increase its amperage, so that it is not only possible to increase the pressure of the current in the secondary coil over that in the primary, but also to decrease the pressure in the secondary coil with a corresponding increase in its current-strength.

61. Comparisons Between Various Coils. — When coils are compared it is customary to simply mention their sparking distance, say 8, 10, 12 inches, or whatever the same may be. This gives no idea whatever of the real power of the coil, any more than when speaking of a waterfall we would say, it is about 50 feet high. How *much* water really flows per minute would be left to the imagination, and an estimate of its horsepower would be simply impossible. The same argument applies to the rating of induction-coils. It is necessary to know not only the *pressure* indicated by the sparking-distance, but also the current *volume*. Two coils may be made to give exactly the same length of sparks, but of very different nature. In one case, it may be thick and intensely white, in the other, thin and bluish. The former coil is the more powerful of the two and the more expensive to build. To send this increased current-strength through the coil, it must be made of heavier wire, both in the primary and secondary coils, with an increased expense both in copper and labor.

As the current in the secondary is not continuous, but interrupted, the current-strength will depend on the volume of current sent through the spark-gap at each interruption. Here, again, a deception is possible. If two coils send sparks of the same volume over the same air-gap, they would be identical, provided this were done at similar intervals. But if one does this at double the number of interruptions per second, then, evidently, double the current volume will cross the air-gap. Some coils can be made to show a high efficiency by slowing down the vibrator. But as the power of the coil, or the number of watts, depends on the product of amperes into volts, it is seen how important it is to ascertain the volume of the current, as the number of watts consumed determines not alone the penetrative power of the rays, but also their rate of action; as, for instance, when used for making a skiagraph. It will also be seen that high pressure, with the resulting high penetration of the rays, is not the only consideration to have in view, in particular if it is bought at the expense of the current volume.

INTERRUPTERS.

62. Simple Spring Interrupter.—The action of the ordinary spring interrupter has already been explained. Its mechanical construction and the various improvements it has undergone since the induction-coil has been utilized for Roentgen ray work will now be described more fully. Fig. 16

represents the form commonly used on coils of moderate size. *H* is the hammer, or armature, on spring *F* facing the platinum point *D* on the end of screw *K*. The latter adjusts the sparking-distance, or angular motion of the hammer. Further means for changing the rate of vibrations is found in the additional screw K_1 near the base, which can submit the spring to an additional tension.

63. Improved Spring Interrupter.—It has been stated previously that it is of the utmost importance to have the current interrupted as quickly as possible. This the vibrator in Fig. 16 is not able to do; it has the two drawbacks of devoting too much time to the act of interruption and too little to the period of contact. It is not enough to give a quick interruption; the current must also be given sufficient time to reach its rate of maximum flow before being interrupted. Otherwise the full strength of the supply current is not utilized. Fig. 17 shows an improvement in the interrupter in which the attempt has been made to attain these advantages. Similar parts having been lettered the same as in Fig. 16, it will be necessary only to describe the additional parts. We notice, then, that the spring *F*, Fig. 16, has been subdivided into two springs, F_1 and F_2. This makes it possible to let the spring F_2 with the armature *H* be in motion while the other spring F_1 with the platinum contact *D* is at rest. The hammer *H* possesses a certain amount of inertia, consequently it is not able to at once attain its maximum speed. In the arrangement shown in Fig. 16, it starts from a position of rest to at once break contact with screw *K*; this interruption takes place, therefore, while it moves at a minimum speed. Again, as a result of the long time spent in interrupting, it can spare no time to leave the parts in

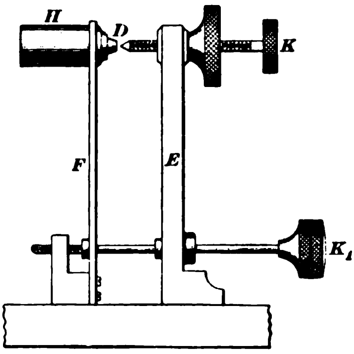

FIG. 16.

contact. In Fig. 17, the hammer *H* can move through a certain variable distance and attain its maximum velocity before a break takes place. This is effected by means of the bracket *I* and adjustable screw *G*, which will not strike the contact spring F_1 before spring F_2 has moved far enough to bring the screw *G* in contact with the insulating plate *g*, when both springs move in unison. This is not all; when the springs return together again, the platinum contact *D* of spring F_1 strikes the screw *K* while both springs are moving at a maximum speed. The latter spring is, therefore, brought to a sudden stop and remains at rest, completing the circuit, while spring F_2 is still moving to the left. When its momentum has been overcome by the new attraction of the core *C*, Fig. 15, it begins again its travel to the right, and the interruptions are repeated.

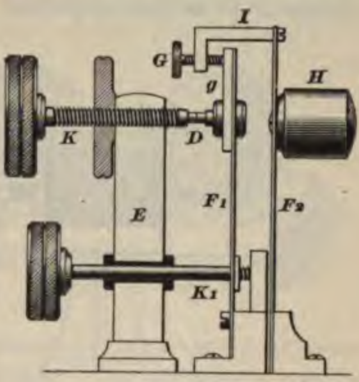

Fig. 17.

It is claimed that this interrupter increases the efficiency of a coil very materially besides preventing sparking and sticking at the contact points. From its increased contact period, whereby the current gets time to reach its maximum strength, a reduced battery power is required.

Most modern spring interrupters are based on the above construction, some small variations being made in allowing the hammer its extra freedom in swinging to and fro. Usually a stem is inserted in the upper part of the armature *H* on which an adjustable counterweight is placed. By its means quite a variation in rate of interruptions may be obtained.

64. Independent Spring Interrupter.—To let the interrupter be operated by the core of the induction-coil is sometimes inconvenient, as variations of the current-strength through the same also influences the rate of interruptions.

This, then, requires a new adjustment of the interrupter to comply with the new conditions. Usually it is desirable to let the rate of interruptions be constant and to adjust the current-strength independently of this. For these reasons it is now customary to let the interrupter be operated in an independent circuit, either in parallel with the main circuit or supplied by a separate cell. A combination of this nature is shown in Fig. 18. S is a small coil with a core C acting on the armature H that is supported by the main spring F_1. The screw K projects through an aperture in the same and strikes against the platinum contact D_1 on spring F_2. When the armature H moves to the left, it reaches the spring F_2, and then both move together in the manner and with the effect already explained. The supplementary coil is supplied with its current through the screw K_1 and contact D_2, both insulated from the main circuit. The rod L, with counterweight L_1, makes it possible to change the rate of vibrations.

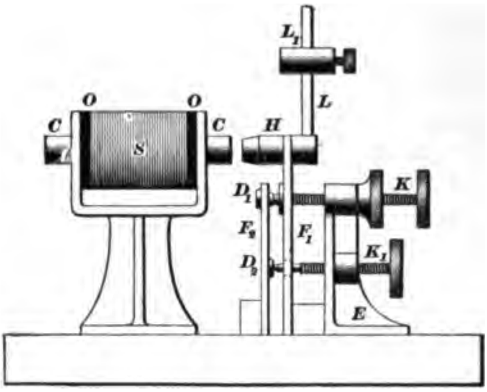

FIG. 18.

65. Edison's Air-Break-Wheel Apparatus.—Instead of the spring interrupter, various others, mechanically operated, are in use. Among these may be mentioned Edison's air-break-wheel apparatus, illustrated in Fig. 19. It consists, in the main, of two metal wheels having serrated edges against which two brushes rest. The wheels being set in rapid rotation by means of an electric motor, and a current being sent through the brushes, an intermittent current will be produced suitable for the operation of the coil. In order to suppress any sparking effects at the brushes, the latter are constantly exposed to an air-blast from two nozzles connecting with a small pressure blower, also operated by the motor. The apparatus may be connected to a 110-volt direct-current circuit, and a suitable rheostat provided to control the current passing through the coil.

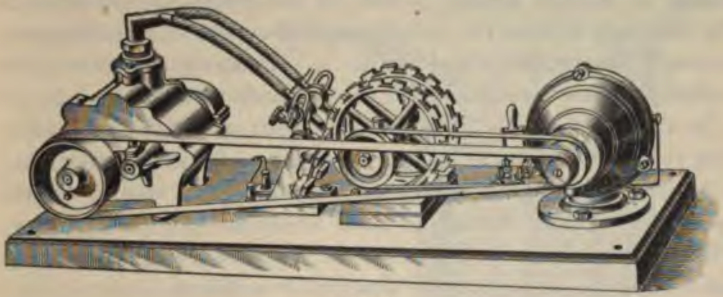

FIG. 19.

66. Mercury Interrupters.—As some inconvenience may result from the irregular wear of the platinum contact points in the spring interrupters, it has been proposed to replace them by a cup of mercury into which a contact rod may dip and be set in rapid reciprocation. The rod may either be operated by a small coil or receive its motion from the crank of a small electric motor. The mercury is, as a rule, covered with a layer of petroleum or alcohol, about 1 inch deep, or even water, to prevent sparking when the rod leaves the mercury.

A recent form of interrupter that has been quite successful is the **mercury turbine interrupter.** Its leading feature may be understood if we imagine the brush in the Edison air-break-wheel interrupter (see Art. **65**) replaced by a stream of mercury. These interrupters have a vertical shaft set in rotation by a little electric motor. The lower end of the shaft consists of a tube having two extensions, one, with a scoop-like opening dipping into mercury, forces a current of the latter upwards and through the other extension in a horizontal direction toward a self-induction I in the circuit. This may consist of a coil of about 100 turns of No. 18 wire into which is placed a core, 10 inches long and about 1 inch in diameter, made of thin iron wires. A partial withdrawal of the core will increase the rate of interruptions. The latter may also be influenced by the active length of the platinum wire, a shortening increasing the frequency. Sometimes the self-induction of the primary coil alone may be sufficient. The general arrangement, when using a direct current from an accumulator, may be seen from Fig. 21, in which B is the accumulator, S the induction-coil, and A the Wehnelt interrupter with glass tube b and lead plate e.

The Wehnelt interrupter may also be used with the commercial alternating circuit, in which case the inductive resistance-coil is omitted. The rate of interruptions is now fixed, depending on the number of alternations in the circuit, which usually amount to from 120 to 160 per second. The current-strength can now be regulated only by changing the active length of the platinum wire, by the density of the electrolyte, or by a rheostat.

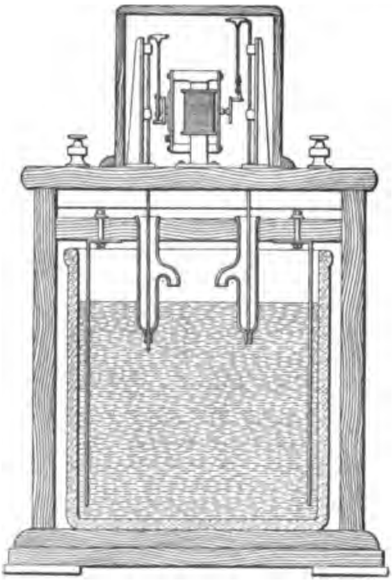
FIG. 22.

68. The Heinze Break.—In some of the electrolytic interrupters the platinum wires are made movable in their glass tubes and given a reciprocating motion. An example of this class is the *Heinze break* shown in Fig. 22. Here the glass vessel is placed in a wooden box on top of which is a small electric motor. The latter is mechanically connected with two platinum wires, which it alternately projects into the electrolyte. The cathodes are, as before, lead plates. It is claimed that this interrupter can stand rough usage and will give a steady light.

69. The Caldwell Interrupter.—Though the Caldwell instrument is usually classed among the electrolytic interrupters, its action is not exactly that of Wehnelt's, but it is more nearly based on the heating effect of the current on a small column of water of high resistance, periodically heating the same to the point of boiling, when the circuit is momentarily broken. Fig. 23 illustrates one of these interrupters with some additions by *Swinton*. *A* and *B* are the two lead electrolytes provided with the binding-posts *E* and *F* suspended from an ebonite cover *G* and projecting into the glass beaker *D*. The electrode *A* is insulated from *B* by a glass tube *C* provided with a small aperture *g*, about $\frac{1}{8}$ inch in diameter, through which a pointed glass rod *c* projects. This glass rod is inserted in a threaded metal sleeve *f*, and engages with a nut *e* by means of which the rod may be raised or lowered, and thus vary the available part of the aperture *g* and at the same time the current-strength. The electrolyte consists of dilute sulfuric acid, about 1 part of acid to 10 or 20 parts of water. Care must be had not to have the beaker too full, as it is the tendency of the liquid in the tube *C* to

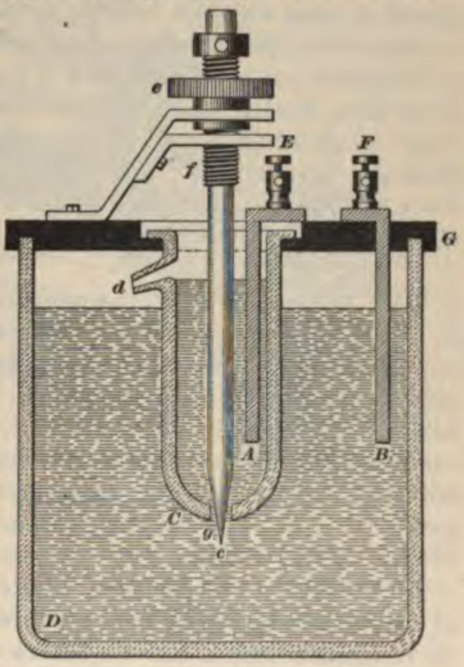

Fig. 23.

raise above that in the beaker. This difference should not be more than enough to allow the overflow to *drip* from the spout *d*; if a small stream should flow from the spout, a short-circuit will occur between the two liquids. The size of the electrodes is the same; it therefore makes no difference in which direction the current flows through the liquid.

When the Wehnelt or Caldwell interrupter is used in connection with an induction-coil, then the condenser and spring interrupter are put out of action and the interrupter is placed in series with and between the coil and the battery. It is claimed that this interrupter greatly enlarges the efficiency of an induction-coil, giving a current of high amperage that is able to produce Roentgen rays of great penetration. At the same time, when using the Wehnelt or Caldwell interrupters, the Roentgen ray tube is liable to overheating, and may be destroyed within a few seconds if it is not constantly watched and the current shut off in time.

70. Induction-Coil Connections.—Having considered in detail the functions of the induction-coil with its various appurtenances, it remains to consider them installed with their correct connections. This subject can very properly be treated briefly, as the variations are numerous, and the operator would rarely feel himself competent to personally undertake the installation of any one of the large modern induction-coils, in particular if its electrical energy should be derived from one of the lighting circuits.

For the sake of completeness, we give in Fig. 24 an example of a coil made by one of the leading firms. It is constructed for connection with a 110-volt circuit and has, for purposes of regulation of current-strength, a rheostat installed in its base, the handle of which is visible. We also notice the interrupter and the switch for adjusting the condenser, inserted in the base. On top of the coil the discharge rods are found, which may be moved simultaneously by turning the milled head until the desired spark-gap has been found. In addition to this, there is also a series spark-gap that acts as a safeguard against an alternating discharge in the main spark-gap by preventing the closing current from bridging across the latter. There is also an interlocking switch, whereby it is impossible to send the main current through the coil before the interrupter is in operation. This is of importance, as, when using a storage-battery, it

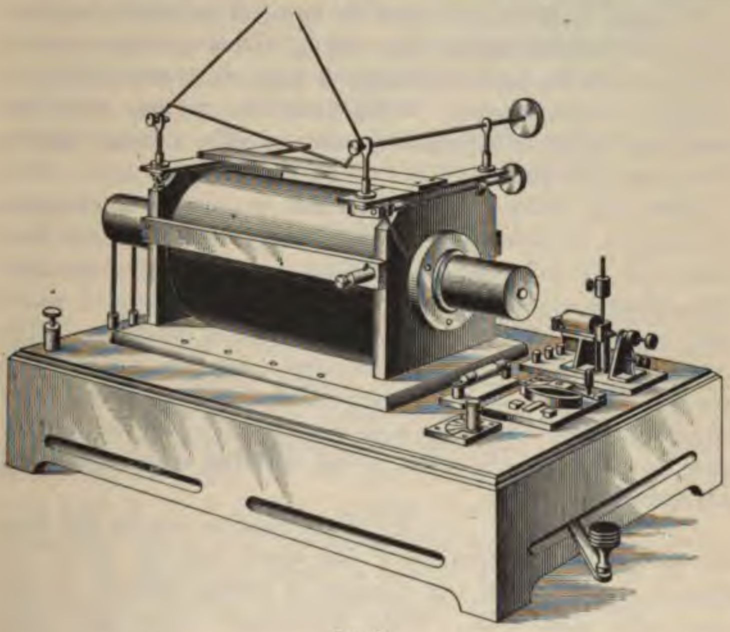

FIG. 24.

would be possible to send a current of 20 amperes or more through the coil, which would be more than an ordinary coil could safely stand and might be the cause of ruining it.

As a coil of this size is a producer of a very high E. M. F. in connection with a rather heavy current, it is important to bear in mind that it is a dangerous thing to handle the coil while it is in action. In particular does this refer to the interrupter, which should not be touched while the main current is on.

It is advisable to have an ammeter in the coil circuit, as an indicator of the current-strength used on different occasions and to guide one when similar experiments must be repeated. A voltmeter is also of advantage, and is indispensable when storage-batteries supply the current, in order to ascertain the existing pressure of the same and to prevent the discharge from going too far with the resulting buckling and sulfating of the plates.

It should be the aim to have the switches needed for manipulation of the coil within easy reach, and a provision should also be made for an extra lamp, or light, that can quickly be turned on when needed. This would be the case when the work is going on in a darkened room, in order to better observe the action of the tube.

When the Edison air-break-wheel or similar interrupters are used, it is customary to locate them in places where their noise will not influence the patient too much. Some manipulators have a special closet for this purpose, the door of which may be closed after it is in proper working condition. The coil may then be on a table near this closet with a rheostat on the wall above same. A switch on the table is within easy reach whenever the current is to be shut off, either for the purpose of changing the tube or for effecting some additional adjustment.

What was said in Art. 44 about polarity applies also here as regards the appearance of the spark and the tube. To ground the poles, for the purpose of testing polarity, is not practicable with coils. When connections have once been correctly made, they should be properly marked to prevent future mistakes.

71. Transportable Roentgen Ray Apparatus. Whenever a patient is in a condition such that his transportation to the Roentgen ray laboratory is impossible, then it is of importance to have apparatus that will allow its transportation without too much inconvenience. If an induction-coil is used, the main difficulty is to find a source of electrical supply. This will be relatively easy if access may be had to the commercial lighting circuit. Mostly, however, this will not be the case, and then recourse must be had to storage batteries. The size of the latter will depend on the coil and the length of exposure.

If a large size is necessary, it is of advantage to divide it in smaller units, placed in independent boxes, that later on may be electrically connected, thus making their transportation more convenient. The coil itself, with the interrupter, rheostat, fluoroscope, plates, etc., is usually housed in a separate box, provided with handles and rollers.

If a medium size Wimshurst or Toepler machine is at hand, then the operator is more independent, as it may be utilized anywhere, entirely independent of any lighting circuit or storage batteries. The motive power may be supplied by hand, as the power required is small and of short duration.

THE TESLA COIL.

72. This coil was formerly considered essential for success in skiagraphy, but it has since gradually lost its superior position. This is caused, mostly, by its additional complication over that of the ordinary induction-coil and by the necessity of having the supplementary coil immersed in an oil bath. It is true that the coil is able to produce currents of a very high E. M. F. and to require very short exposures for skiagraphs, but it has been found that the ordinary induction-coil, in its improved forms, is able to give all the E. M. F. and current that the Roentgen ray tube, in its present form, is able to stand.

In the Tesla coil, an alternating current is sent through a primary coil that acts inductively on a secondary coil, as in other induction-coils; but instead of using the secondary current directly for operating the Roentgen ray tube, it is sent into a condenser. By this means the current is set into very rapid oscillation, about ten millions per second, and is then sent through the primary of a supplementary induction-coil, where it again induces a secondary current of a still higher potential in another secondary coil. Both of the latter coils have very few windings and are inserted in oil to insure perfect insulation.

THE ROENTGEN RAY TUBE.

NATURE OF THE ROENTGEN RAYS.

73. Their Relation to Other Rays.—The whole subject of Roentgen rays is one on which many conflicting opinions exist. To say positively what the Roentgen ray really is, whether light, an electric current, or a stream of molecules, all of which propositions have been held, seemed at first very difficult. Nevertheless, the field has been made somewhat clearer since Roentgen made his first exhibition in 1895, when he expressed the idea that Roentgen rays might be longitudinal vibrations of the ether. This explanation of the problem has been abandoned, and there is now little doubt but that the Roentgen rays belong to the light phenomena and occupy a place in the spectrum beyond the invisible *ultra-violet* light in a class that may be called *ultra ultra-violet*. They would seem to be, therefore, transverse ether waves.

In Fig. 25 a diagram is given indicating the position of the optical, chemically active, heat rays, and electromagnetic ether waves. On the extreme right we find the Roentgen rays. The length of the waves are given in microns. One *micron* is one-millionth meter or .001 millimeter. The ultra-violet and the Roentgen rays have these properties in common, that they produce fluorescent and chemical effects in various substances, and that they are able to discharge electrically charged bodies.

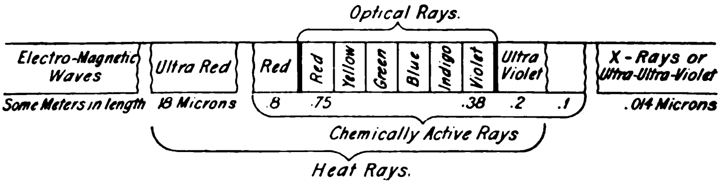

FIG. 25.

74. Typical Roentgen Ray Tube.—The apparatus commonly used for the production of Roentgen rays is so universally known that little need be said here. Fig. 26 shows the fundamental form, in which the cathode is on the left, consisting of a concave circular reflector of aluminum, and the anode on the right, made in the form of a smooth polished disk of platinum. At either end are terminals that may be connected with the negative and positive conductors of the induction-coil. The usual description of Crookes tubes and the effects obtainable at various degrees of exhaustion will be omitted, as it is more of historical interest, and may be found elsewhere.

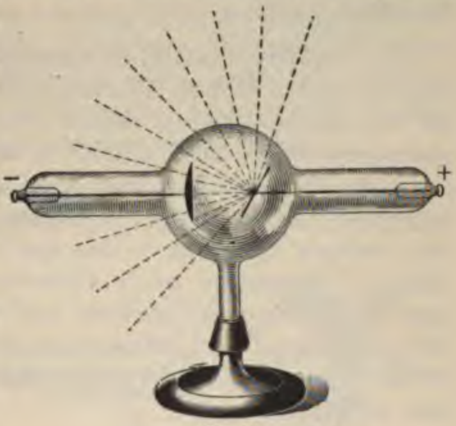

FIG. 26.

75. The Vacuum of Roentgen Ray Tubes. — The main point aimed at in the production of good Roentgen ray tubes is the attainment of a suitable vacuum. The whole manipulation necessary for this result is more or less empirical, and the products very variable in their qualities, no two tubes being exactly alike. When considering that the pressure in the tube has been reduced to from 1 to 2 millionths of the atmospheric pressure, and that little variation is allowed, it will be understood that their production is not an easy matter, if uniformity is required.

76. Radiant Matter.—When the pressure in a tube has been decreased to this extent, the remaining gas is said to be in a "radiant state." This means that so few molecules remain that they are able to travel in space for relatively long distances without colliding with one another. They then constitute "radiant matter."

77. Cathode Rays.—We may then presume that the molecules receive a negative charge from the cathode and are forcibly repelled from the same, attaining a velocity of about 62,000 miles per second. They will travel in paths at right angles to the surface from which they receive their negative charges, and it is, therefore, possible to predetermine the direction in which they will proceed. This collection of repelled molecules is called *cathode rays*. On the direction of these rays the anode has no influence and may be situated anywhere in the tube.

78. Transformation of Cathode Rays.—By giving the cathode the curved form indicated in the figure, it is possible to let the molecules radiate toward a common center and there concentrate the resulting effects. It is now assumed that the molecules, or atoms, when they strike the anode, are set in rapid vibrations. Their *mechanical* vibration may be transformed into ordinary light, but in this case it is assumed that their electrical charges are set in vibration, that it therefore is a question of *electrical* vibrations and that these vibrations of electrical charges may produce the Roentgen rays. In other words, it is a kind of electrical surging and splashing effect that takes place.

79. Function of the Focusing Point.—It must not be assumed that the Roentgen rays are *reflected* from this focusing point of the cathode rays in which the transformation takes place. Rather must this point be considered as a source of light from which the rays radiate in all directions. If the anode were perfectly plain and highly polished, the rays would radiate even in a direction nearly parallel with the surface, but as these conditions are not fulfilled, they will decrease in strength as they approach an angle of about 2° to 3° with the plane of the anode.

That place on the anode where the cathode rays meet should be a point, but in reality it is a circle. Its diameter should not exceed .04 to .08 inch if skiagraphs with clear outlines are desired. From observations made by Dr. Gocht, Berlin, it seems that this little circle is not the real source of the Roentgen rays, but rather a ring-like surface immediately adjoining it.

It was found that a number of tubes in which the anodes had been punctured by the effects of heat showed an undiminished production of Roentgen rays, notwithstanding the fact that a large portion of the rays would seem to pass entirely through the anode.

In the tube, as originally constructed, the cathode rays were allowed to strike the walls of the tube. If, under these circumstances, the rays were focused to a common point, then the results were that the heat resulting from the atomic bombardment was enough to melt and puncture the glass. If, on the other hand, they were dispersed over a larger area, then the Roentgen rays had to pass through a larger surface of glass with a greater loss from absorption by the latter.

80. Anticathode.—In some tubes, the anode does not act as the focusing point of the cathode rays, but is placed somewhere else in the tube. It is then replaced by a so-called *anticathode*, which should be in electrical connection with the anode. Fig. 27 gives an example of this class. The terms anode and anticathode are not always kept separate, and the term anticathode is often used when speaking of the anode.

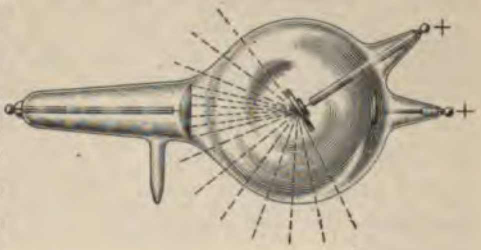

FIG. 27.

81. Modern Forms of Roentgen Ray Tubes.—The more modern form of the Roentgen ray tube is made in the shape of a large globe with tubular extensions projecting in diametrically opposite directions. The globular form serves two purposes. A vacuum tube must be able to withstand a large external pressure, about 700 pounds, and it is found that a globe is able to do so with the least amount of material in its walls. It is important that these are as thin as possible, less than $\frac{1}{64}$ inch, in order not to have too much of the Roentgen light absorbed by the glass. Another reason for choosing the globular form is the greater distance that it allows between its walls and the anode, therefore not exposing the former so much to the heat of the latter.

As already stated, the maintenance of a constant pressure in the Roentgen ray tube is the point of prime importance in Roentgen ray work, and, in reality, all the efforts of the operator center around this one point. The rest of the technique dwindles in importance compared with this one item.

82. **Variations in Pressure.**—The reasons for variations in pressure are the following: When a current is passing through the Roentgen ray tube, a certain amount of heat is generated by the cathode rays striking the platinum disk and the glass walls. As the tube is increasing in temperature, the vacuum is lowered and an increased amount of current passes through. Consequently, the heating and lowering of vacuum is doubly accelerated. Unless, therefore, the heat is dissipated as quickly as it appears, the tube will be in a very unstable condition. Then again, if a tube gets colder, an increase in vacuum results; therefore there is greater resistance for the current to overcome; less current will pass through and less Roentgen rays will be generated. It is seen, then, that it is only when a proper balance exists between the heat generated and dissipated, that the illuminating capacity of the tube remains constant.

83. **Increase of Vacuum.**—Even if this balance could be accomplished, a tube would, nevertheless, gradually change after having been used for some weeks or months, its vacuum growing higher and higher. This is caused by the gradual occlusion of the radiated matter in the walls of the tube. The number of active atoms will, consequently, grow less. The rays produced by them are growing in penetration, because the path of the active atoms is more free and they are able to strike the platinum with maximum velocity; but after a while it will be impossible to send any current through the tube, even with the highest pressure, because no carriers are at hand to transport the charges from the cathode to the anode, and the current will now, in preference, pass around the outside of the tube.

It has been found that this increase in hardness is very much slower with a static machine than with an induction-coil.

84. Means for Lowering the Vacuum.—When a tube has reached this stage, means must be found to lower the vacuum. The most primitive method to pursue for this purpose is the heating of the tube either by means of a gas or alcohol flame. While the heating is going on, a weak current is allowed to pass through the tube, and care must, therefore, be taken that neither the gas-jet nor the alcohol lamp comes too near the tube. In the latter case an explosion of the lamp may occur, and in the former the current may pass through the burner and the tube, unless this burner is made of glass.

All operators have come to the conclusion that the heating of the globe itself or its anticathode extension does not compare with the effect produced by heating the surroundings of the cathode. This heating must not be limited to one place, but should be evenly distributed so as to prevent cracking the tube. The effects produced seem to be a removal of static charges situated near the cathode and, thereby, also the attracted air particles. At the same time, the heat causes the expansion of the glass walls, thus releasing the air contained therein.

Another and more effective method is based solely on the removal of the static charges mentioned above. This effect is obtained by winding a strip of gauze, consisting of three layers 12 inches long and about ¾ inch wide, around the extension that contains the cathode. If the cathode extension is turned to the left, the strip should occupy a position so that its right-hand edge is in line with the edge of the cathode reflector. Before winding the strip on the tube it should be dipped in water, wrung out well, and wound tightly and evenly around the tube.

85. Means for Increasing a Vacuum.—Sometimes it happens with tubes having an adjustable vacuum that too much air has been released, and that the vacuum, consequently, is so low that a bluish light has made its appearance. This can be remedied either by letting the tube cool off somewhat, accelerating this by the fanning of cool air toward the tube, or by reducing and reversing the current and letting it pass through for a few seconds.

86. Suitable Tubes.—In order to get the most use out of a tube, only those having a low vacuum should be procured. To buy a tube with a vacuum corresponding to the maximum sparking distance of the apparatus, would be a mistake. Several tubes should be on hand that have passed through the various progressive stages of hardening, and that one selected that harmonizes with the desirable sparking distance.

87. Care of Tubes.—It is needless to say that the tubes should be stored away with care, not exposed to accumulations of dust and dampness. In any case, they should always be wiped off before using, and in damp weather it may sometimes be necessary to give them a preliminary heating to counteract the influence of humidity.

ROENTGEN RAY TUBES WITH ADJUSTABLE VACUUM.

88. Classes.—Roentgen ray tubes, constructed for the purpose of overcoming these difficulties, may be divided in two classes: (1) Tubes that tend to prevent the overheating by means of increased radiating surface. (2) Tubes that set an extra amount of gas free when the original amount is decreasing.

Among the first class may be mentioned tubes having heavily backed anticathodes with thick metal stems to facilitate the heat radiation. Also, tubes provided with a circulation of cold water with the same purpose in view.

In the other class may be included tubes with a supplementary pocket in which is deposited a substance that, when heated, will give off a certain amount of air or other gases to replace the occluded gases. These various forms are more or less successful, but demand constant attention.

89. Self-Regulating Tube.—A tube that would automatically regulate the supply of extra gas required for the maintenance of the proper vacuum would be of advantage, and various experiments have been made with this point in view. Among the most successful of these is undoubtedly the self-regulating tube, Fig. 28, made by Queen & Co., of Philadelphia. The small tube *E* contains a chemical which gives off vapor when heated and reabsorbs it when cooling; it is directly connected to the main tube, and is surrounded by an auxiliary tube *D*, which is exhausted to a low vacuum. In the auxiliary tube the cathode *a* is opposite the above-mentioned bulb, so that any discharge through it will heat the bulb by the bombardment of the cathode rays. The anode *b* of the small tube is directly connected to the anode *B* of the main tube. *A* is the main cathode and *M* the platinum disk. *R* is a movable rod by means of which the spark-gap *R d* may be regulated. An extension *N* permits the tube to be fastened in a holder.

The tube, itself, being of a high vacuum, will offer considerable resistance to the current, and the latter will therefore take the easiest path and jump across the gap *d R*. This will send cathode rays toward the protective platinum tip *D* and heat the bulb *E*, sending a vapor into the main tube, which will continue

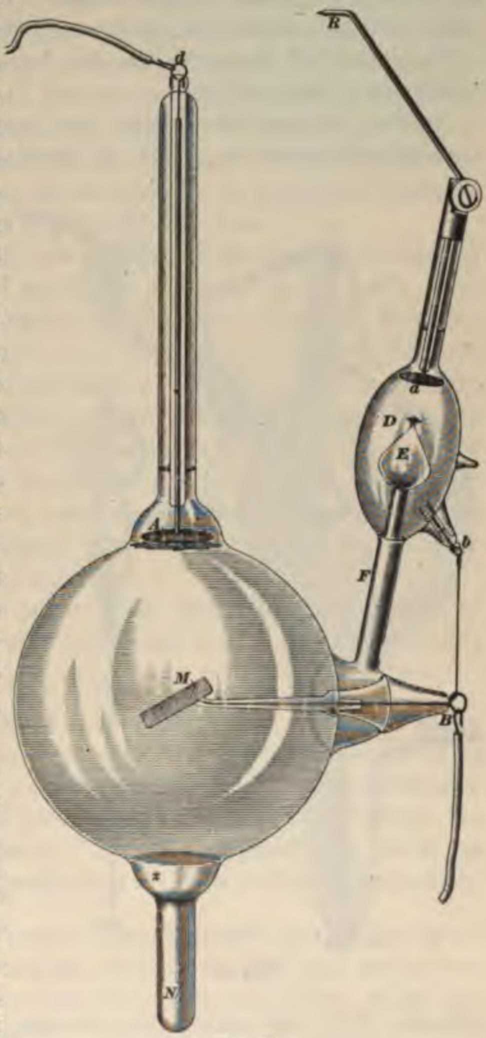

FIG. 28.

for a few seconds until the vacuum has been reduced sufficiently to permit the current to pass. After this an occasional spark will pass across the gap to counteract the tendency of the bulb to cool off and reabsorb the vapor, thereby raising the resistance of the main tube.

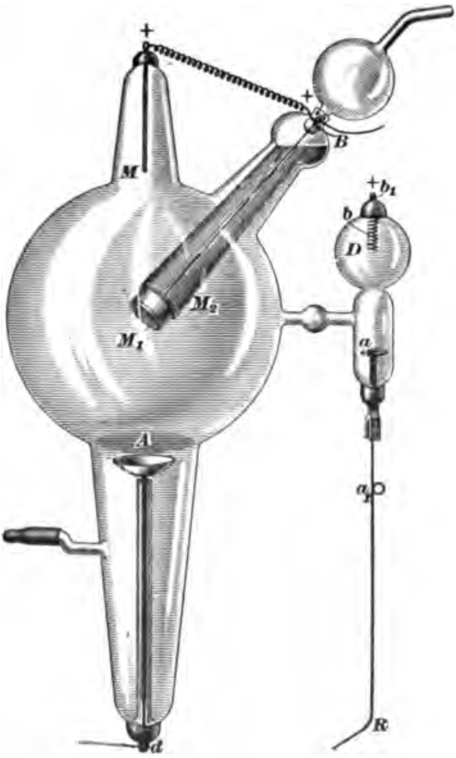

FIG. 29.

Another self-regulating tube, very similar in construction, is that manufactured by C. H. F. Müller, Hamburg. It was recently awarded the gold medal by the Roentgen Society, London, for its efficiency and high capacity, its main principle being that of the last-mentioned tube; the parts performing the same functions are marked with similar letters. The tubes may be had with or without water cooling, Fig. 29 illustrating one of the latter class. *A* is the cathode, *M* the anode, and M_1 the anticathode, supported by the glass tube M_2. This tube may be supplied with a constant stream of cold water for the purpose of carrying off the heat generated in the anticathode, thus preventing its overheating and destruction. *D* is a supplementary tube directly connected with the main tube and provided with an anode *b* and cathode *a*. *R* is a brass rod which, in conjunction with the terminal *d*, constitutes the adjustable spark-gap.

The auxiliary cathode *a* is made of a material that will release a certain quantity of gas as soon as sparks are allowed to pass between *d* and *R*. An adjustment of the vacuum will then be effected in a manner similar to that of the Queen tube. Should the vacuum have become too high for immediate reduction in this manner, then the negative conductor may temporarily be connected directly to the auxiliary cathode terminal a_1. Some care is required so as not to make the vacuum excessively low, and 2 or 3 seconds is generally sufficient.

If it is required to at once make the tube into a high-vacuum tube for the purpose of making a skiagraph of the pelvis, then it is only necessary to remove the positive conductor from the terminal *B* to terminal b_1 and operate the tube until the rays have acquired sufficient penetration. This increase in vacuum is caused by the molecules, which, after being torn from the anode *b* and driven away, will settle on the surrounding walls and occlude a certain amount of gas. During this operation *d* and *R* must be beyond sparking distance. The time required depends on the previous state of the tube and may, if the latter is very soft, amount to 5 minutes.

Improvements in tubes are made constantly, but it is well to select a good tube of standard make and to become familiar with it before beginning to experiment with new variations.

90. Theory of Hard and Soft Tubes.—The difference between what are termed "hard" and "soft" tubes, as far as their differentiating powers are concerned, will be stated further on, but an attempt will here be made to find an explanation for the cause of this difference. It is not claimed that this is the correct one, but it is thought that it points in the right direction.

91. The Hard Tube.—As explained above, the atoms repelled from the cathode are similarly charged, and are moving with great velocities toward the platinum anode, where the charges are transformed into Roentgen light, or X-rays. When moving in the very high vacuum of a *hard tube*, the paths followed by the atoms are rather free from obstructions, and they are able to strike their points of destination with maximum velocity, and their charges will therefore be set in a *maximum* rate of vibration, producing a light of *minimum* wave-lengths. It is presumed that these wave-lengths are so small that they are able to penetrate matter without meeting much obstruction. On the other hand, it would be easy to understand that the rays would penetrate substances between which the difference in density is not very great with about the same facility. It would therefore make a small differentiation between such objects when skiagraphs are taken.

92. The Soft Tube.—The conditions are different when the current passes through a tube of lower vacuum, or a so-called *soft tube.* There are, then, a greater number of atoms in action in all directions, and those that radiate from the cathode are more numerous, but no longer pass so freely toward the anode. They collide again and again, and finally reach their destination with a greatly reduced velocity. The rays that are now produced do not possess the high rate of vibration and, therefore, not the short wave-lengths, and will not pass so freely through matter as in the other case. Substances of varying density will have more effect on the rays and absorb them more freely. These rays have not the power to penetrate dense or thick objects, but are able to give better differentiation between substances, such as tissues of the human body, that are not very different if density alone is considered. On the other hand, from the increased strength of the cathode stream, there are more numerous charges transferred to the anode, and a heavier stream of rays will proceed from the anode, resulting in a greater activity on a photographic plate.

93. Functions of Hard and Soft Tubes.—Hence we come to the conclusion that when it is a question of penetrating power alone, then a tube with a *high* vacuum should be used, and when the difference between objects of small and somewhat similar densities should be emphasized, then a tube of *lower* vacuum is more useful.

In fact, the tube should have a vacuum just high enough to penetrate the densest part of the object to obtain maximum differentiation. The more the vacuum proceeds beyond this point, the more tendency will the rays have to exert an equalizing action and to obliterate differences in density. Consequently, the denser the body the higher the vacuum.

For instance, a bullet imbedded in a dense part of the body requires a high vacuum. On the other hand, a bullet situated in the arm requires a lower vacuum, but still high enough to make distinction between the bullet and the bony structure. Going down to still smaller densities, such as the hand, a still lower vacuum is required for good differentiation.

In these investigations of the penetrating quality of the Roentgen rays, the fluoroscope is not to be taken as a *direct*, but more as a *comparative* guide. The fluoroscope demands a much higher vacuum for observing the same parts, if a fluoroscopic examination is to give good results. For instance, the rays suitable for giving a good *skiagraph* of the hand or arm would let the bones appear dark in the fluoroscope.

In the same manner, if the presence of calculi is to be ascertained by means of a skiagraph, then enough penetrating power should be given to go through substances a little denser than the surrounding tissues, but nothing more.

Where differences in densities are small, it is important not to go much beyond the penetration required for the densest parts, if maximum differentiation is looked for.

By inserting a spark-gap between the terminals of an induction-coil and the tube, that is, in series with the tube, quite a change may be effected in the character of the rays. This gap is usually arranged on the cathode side. Gardiner made exhaustive experiments in this direction and found that the greatest effects were produced with a soft tube. The change from no spark-gap to one ½ inch long, varied the penetrability of the rays at the ratio of 7.3: 10.66.

When such a spark-gap was used with a static machine, as, for instance, by means of the interrupter, he found the change in penetrability still greater. The degree and magnitude varied in different tubes, and the variation was the greatest when using a large and moderately hard tube. With a tube of the latter class the change in penetration was at the ratio of 2.7: 4.8 when no spark-gap and one of 1 inch in length was inserted.

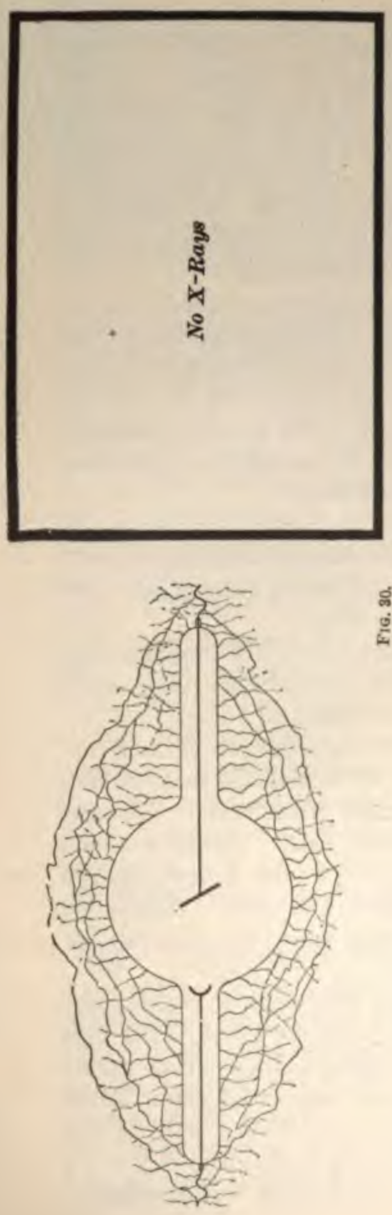

FIG. 30.

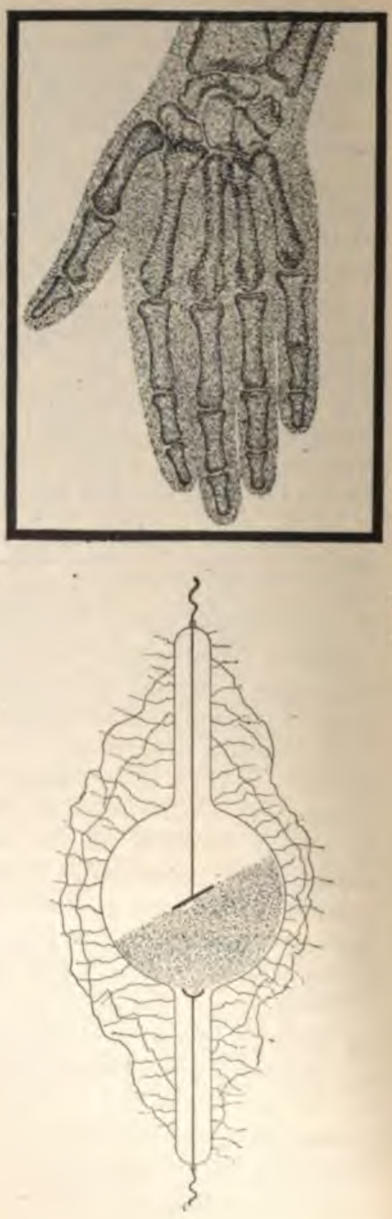

FIG. 31.

94. Examples of Hard and Soft Tubes.—To make this subject still clearer, we give below some illustrations that show the relation between the hardness of a tube and the skiagraph that it is able to produce. For this purpose we will divide Roentgen ray tubes into five classes.

1. Tubes *too hard* to permit any current to pass from the cathode to the anode. The current will, therefore, to a great extent, pass outside the tube, and no rays will be produced. Fig. 30 is made to represent this condition. The irregular lines outside the tube are intended to indicate the existing electrical discharges outside the tube.

2. *Hard Tubes.*—In these, part of the current goes through the tube and produces rays of great penetration, but too great for a contrasting skiagraph of the hand and parts of similar density. Tubes of classes 1 and 2 show little fluorescence of the glass. The amount of this is indicated by the depth of shading given the lower part of the tube globe, as seen in Fig. 31, which illustrates a tube of this class with the resulting skiagraph.

3. *Medium soft* tubes, producing rays in quantity and of good penetration, and which have the greatest field of usefulness, are illustrated in Fig. 32. The increase in fluorescence is indicated by the deeper shading of the globe. We find here a skiagraph rich in contrast and giving strong outlines to the bony structure. There is still some exterior discharge along the tube. None of the tubes in these three classes can be touched without more or less danger of getting a severe shock, which is not the case with the following two classes. In the latter the current goes wholly through the tube and can be touched without drawing a spark.

4. *Soft Tubes.*—The amount of light produced is still plentiful and gives extreme contrast to the skiagraphs of objects possessing small depth. But the penetrating power is already on the wane and the rays are no longer able to penetrate the denser parts of the bones. Fig. 33 indicates the condition of the tube and gives a skiagraph with strongly outlined tissue parts of the hand.

*5. *Too Soft Tubes.*—We are now arriving at the other

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* We are indebted to Dr. R. Kienboeck, of Vienna, for these instructive illustrations.

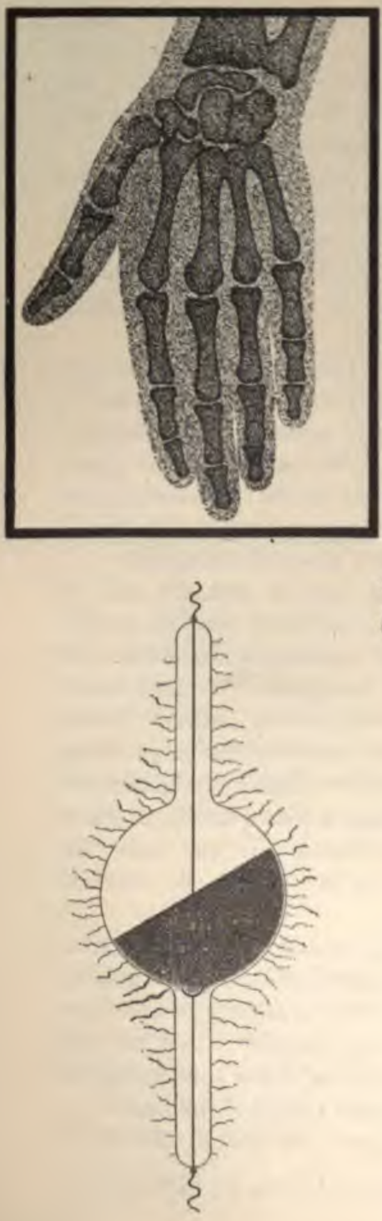


FIG. 32.

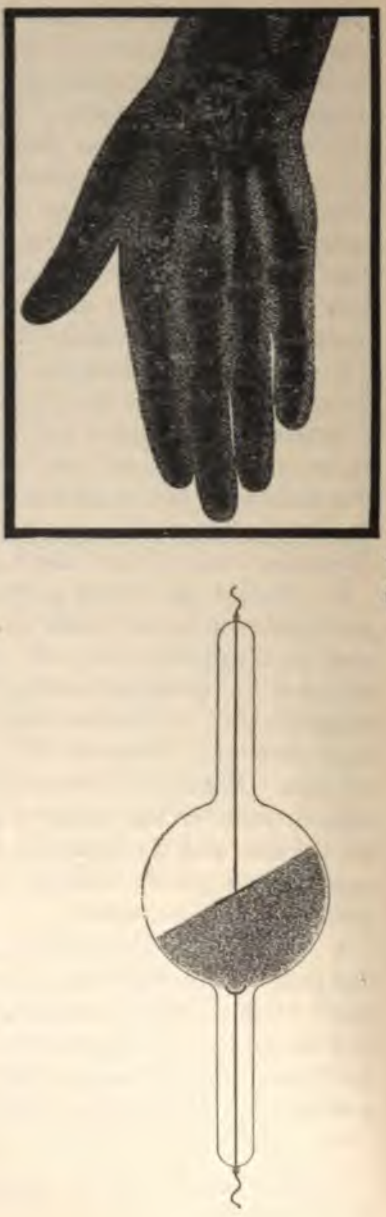


FIG. 33.

extreme, and have here tubes through which the current is able to pass freely, but is unable to produce Roentgen rays because the air-pressure is too high, or in other words, the vacuum is too low. There is nothing but the violet light found in Geissler tubes. The presence of this light is indicated in Fig. 34 by means of transverse shadows.

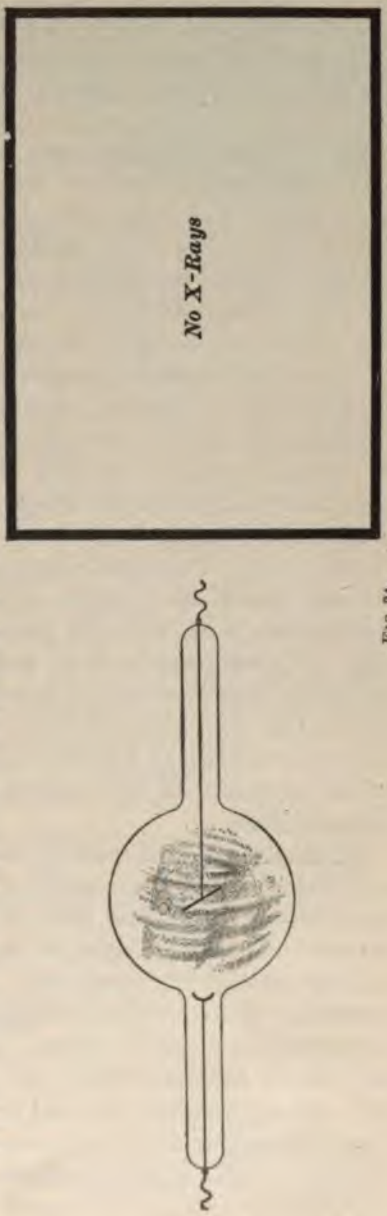


FIG. 34.

DERMATOLOGICAL EFFECTS OF THE X-RAYS.

95. General Effect. From the very first introduction of Roentgen rays in therapeutics, various effects have been noticed, on and off, on those parts of the skin that were in immediate proximity to the tube. In some instances, when the exposures were prolonged, these effects have been very serious, resulting in serious inflammation and gangrene, requiring months or even years to repair. In other instances, the right hand was affected from its frequent interposition between the tube and the fluoroscope for the purpose of testing the intensity of the light.

The effects seem to vary in different persons, in some producing nothing more than a reddening of the skin similar to that received by a stay at the seashore.

96. Effects of Hard and Soft Tubes.—The cause of these inflammations has not been definitely determined, and two solutions have been offered. One is that the rays themselves are the direct cause, while others contend that they are caused by electric charges sent out from the tube. The subject has been closely studied in Germany, and two parties have been formed which defend the two opposing ideas just quoted.

In order to decide this question finally, if possible, Dr. Robert Kienboeck, of Vienna, proceeded to make a long series of investigations, in which he exposed a number of persons to tubes of very high vacuum belonging to class 2, Art. **94**. The sittings lasted in general for about 10 to 15 minutes, while the distance between the tube and the patient amounted to about 6 to 10 inches. The spark length of the coil used was 12 inches, and the current derived from a 110-volt lighting circuit. The interruptions were 15 to 20 per second. After giving 80 sittings, few effects were noticed and what dermatological results did follow had been healed simultaneously with the sittings. During this time the tube had been growing in hardness. It was now replaced by a softer, self-regulating tube, and after 2 weeks' treatment, all the patients were suffering from intense inflammations.

Dr. Kienboeck then came to the conclusion that it is not the electrical charges that are active on the skin, but the Roentgen rays themselves, and that the more numerous the latter are and the more contrasted skiagraphs they give, the more active they are, dermatologically considered. He also found that a certain connection exists between their dermatological and their fluoroscopic and photographic effects. For instance, the softer tubes that pass a heavier current, but of relatively low voltage, act more strongly on the skin and are also best suited for fluoroscopic investigations, giving a strong light. They are also very effective in their action on the photographic plate, diminishing the time for exposure to a great extent. The hard tubes, on the other hand, giving fewer but more penetrating rays, produce less fluorescence, and their action on the photographic plate must be prolonged through a longer period of time. As these actions are chemical, it is suggested that the effects of the Roentgen rays on the skin are also chemical, similar to those caused by sunlight, but highly intensified.

This view on the cause of dermatitis following Roentgen ray exposures is confirmed by the investigations of Branly, Lucaille, and Oudin, and which was communicated to the Electrotherapeutic Society, of France, by Oudin, in June, 1901. In this communication they state that the Roentgen rays alone are responsible for the dermatitis. Straeter divides the life of a tube into four periods. In the first, the tube is very soft and very poor in Roentgen rays, producing no effects on the skin. It gives on the fluorescent screen a black shadow of the soft parts. During the second period the shadows of the soft parts appear still dark and those of the bones very dark, the middle of the phalanges being hardly transparent. In this state the tube is very rich in rays, endowed with relatively feeble penetrating power and produces superficial dermatitis. During the third period the tube is very rich in rays of marked penetrating power; they produce profound dermatitis. On the screen they scarcely show the soft parts, and the bones appear very pale. Finally, in the fourth period, the tube has become very resistant, and nearly the whole electric current passes around it. The shadow of the bone has almost disappeared, and the tube lights up only at intervals, producing only few rays of intense penetrating power that are no longer able to produce dermatitis.

That the Roentgen rays are the active factors in the production of dermatitis is the opinion of the majority of authors now occupying themselves with the study of the effects of Roentgen rays in diagnosis and therapeutics. It seems quite safe, then, to affirm that it matters little what the source of the electric current is, or even if the latter is present at all, as shown by an incident related below, the cutaneous effects in skiagraphy are proportional to the number and to a certain penetration of the Roentgen rays, and that these two factors depend wholly on the quality of the Roentgen tube.

That an electric current is not necessary in order to produce Roentgen ray dermatitis is clearly demonstrated by an accident that happened to Becquerel, the discoverer of the rays that bear his name. Becquerel, by carrying in his vest pocket a small glass tube containing a few centigrams of radium, produced on his own person a grave form of dermatitis.

97. Affected Area.—It has also been found that the spot where a line, drawn from the center of the anode at right angles to the skin surface, meets the latter, is the part where the effects first begin to show themselves. The reason for this is that this place is nearest the source of the rays and that the latter are more numerous around this center line. From this spot outwardly, the dermatological effects are gradually decreasing in intensity. The whole affected area is circular, and the diameter depends on the proximity to the tube; it is larger when farther away, but a longer time is then required to obtain the same results. The healing of the affected parts begins at the periphery and proceeds toward the center, where the symptoms are the last to vanish.

That the rays are the active element was further proved by the fact that whatever forces acted on the skin proceeded from one common point. Variously shaped shields of lead were interposed between the tube and the skin and in every case the skin affections corresponded in area to those that would have resulted if the rays had proceeded from one common point.

If these conclusions are correct, then substances that are impervious to Roentgen rays should prevent dermatitis, while other substances that prevent electric charges from reaching the skin should be inoperative. The fact was that a sheet of rubber, which prevented electrical effects but allowed Roentgen rays to reach the parts, was no prevention against dermatitis. A glass plate and a triple layer of tin-foil protected the skin to some extent. But the most surprising effects and conclusive proof was obtained by the experiment illustrated by means of Fig. 35. Here the tube was so placed that the anode was at right angles to the arm and at a distance of 6 inches. The Roentgen rays would then proceed only from the left side of the globe and would be limited in extent by the lead plate *a*, which would permit no rays to pass. The dermatitis was, in fact, produced on the spot marked by small dots, and there only. If caused by electric charges it would have extended from plate *a* to *b*, as the charges would proceed from all over the tube. These experiments do not of necessity prove that it is the photographically active Roentgen rays that produce these results. It is well known that the rays are combined of various varieties differing in wave-lengths, and it may be that rays of relatively greater wave-lengths are the really active agents.

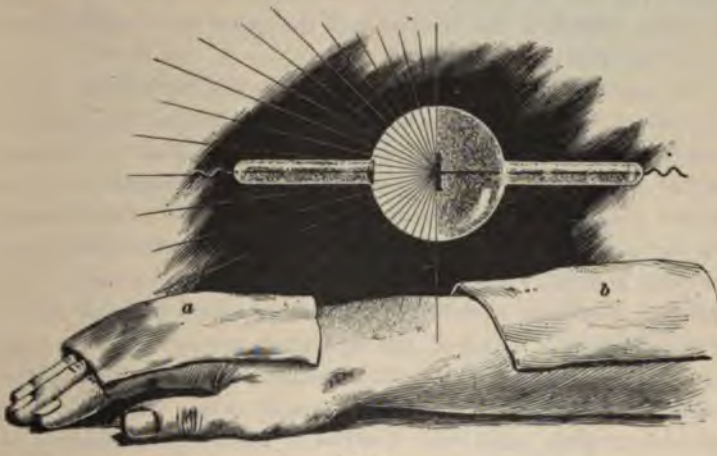


FIG. 35.

98. Preventive Means.—After all these experiments as to how to *produce* dermatitis, let us now see what means are at disposal to *prevent* it. The interposition of a cardboard coated with tin-foil or gold-foil, connected to the earth, has repeatedly been recommended as an effective preventative. This would be correct if the cause were of electric origin.

As really effective, the following rules should be followed: The patient's body should never be nearer the tube than 6 inches. By fluoroscopic investigations through the body, the time should never go beyond 15 or, at most, 30 minutes, in particular when very active rays are used. In the making of skiagraphs there is less danger of affecting the skin, as the time is rather short when good coils are used. For instance, a skiagraph of a hand at 12 inches distance has been taken in 10 to 30 seconds, while that of a head, thorax, or pelvis required ½ to 2 minutes, at a distance of 24 inches. To have the tube nearer is not advisable if the parts shall retain their proper relation to each other.

The operator, who is daily exposed to the rays, needs more protection than the patient, in particular during fluoroscopic examinations. In general, it may be said that he should expose himself as little as possible to the Roengten rays; he should place himself in the field of the dark half of the Roentgen ray globe. When obliged to work in the active field, then his body should be shielded as much as possible by that of the patient. His body should otherwise be shielded by lead plates, as supplied with some of the operating tables, and the tube itself should be encased in a box coated with white lead on the inside to make it impervious to Roentgen rays. This box may have a revolving plate with a series of apertures, either one of which may be used, depending on the area the rays have to cover. Otherwise no Roentgen rays leave the box. In addition to this, the box will act as a safeguard in case the tube should explode, which happens sometimes quite unexpectedly. Such boxes are furnished by the trade.

PERMEABILITY OF THE HUMAN BODY TO ROENTGEN RAYS.

99. Comparative Permeability.—The permeability of various substances to the Roentgen rays is, as a rule, inversely proportional to their specific gravity. On the following page we give some of the more important materials with their specific gravities and their permeabilities, or transparencies. Water is taken as unity in both, and those of the greatest transparency are placed at the head of the list.

100. Relative Permeability of Parts of the Body. The various parts of the human body have a varying transparency, not alone as to different parts of the same body, but same

PERMEABILITY AND SPECIFIC GRAVITY OF VARIOUS SUBSTANCES.

Substance.	Specific Gravity.	Transparency.
Pine	.56	2.210
Paraffin . . .	.87	1.120
Rubber . . .	.93	1.100
Water . . .	1.00	1.000
Ebonite . . .	1.14	.800
Charcoal . .	1.16	.630
Bone	1.90	.560
Aluminum . .	2.67	.380
Glass . . .	2.70	.340
Tin	7.29	.118
Zinc	7.16	.116
Iron	7.78	.101
Nickel . . .	8.51	.095
Copper . . .	8.92	.084
Silver . . .	10.24	.070
Lead	11.39	.055
Mercury . .	13.59	.044
Gold	19.63	.030
Platinum . .	21.53	.020

parts of the different bodies also show some difference. In general, the following differentiations may be made:

1. *Bones* are less transparent than the surrounding tissues, and the more lime they contain the less transparent they are. Not alone can bones be studied in their normal condition, but the location and condition of broken or dislocated parts can also be observed.

2. The *muscular layers* have a medium density, somewhat similar to that of the internal organs, such as the kidneys, liver, etc.

3. The tissues of *blood-vessels* and *nerves* are a little more dense than the surrounding muscles, but not enough to make any distinction between them.

4. *Foreign bodies* imbedded in the muscles or internal organs are of so much greater density than the latter that they can easily be distinguished. Among these may be mentioned bullets, splinters of metals, stone, or glass, etc. *Trichinæ* when calcified may likewise be detected.

5. *Calculi* in the bladder have also been observed, but require most careful manipulation of the Roentgen ray tube and negative.

DEFINITIONS OF OBJECTS IN A FLUOROSCOPE OR ON A SENSITIVE PLATE.

101. Requirements for Sharp Definition.—To obtain Roentgen ray pictures in which the objects are clearly outlined, it is necessary that the latter should be as near the sensitive plate as possible. The further an object is removed from the plate and the nearer it comes to the Roentgen ray tube, the more will it lose in sharpness of outline and detail. The rays proceeding from object to plate will grow more and more diffused and finally will not reach the sensitive plate at all, or, at least, not visibly so.

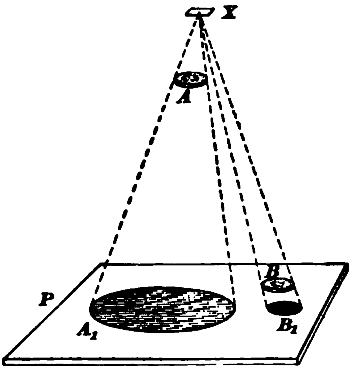


FIG. 36.

Fig. 36 will make this phenomenon more clear. Let X be the platinum anode in a Roentgen ray tube and P a sensitive plate. If, now, a coin B be held in the position indicated, it will throw a dense shadow B_1 of a diameter very nearly that of the coin. It will be seen at once that the nearer the coin and the shadow come together, the more their dimensions will coincide.

Another coin A, placed near the illuminating source X, will throw shadow A_1, which is of a much greater diameter than that of B_1, but also of much less density. The dimensions of the shadows are inversely proportional to the distance of the object from the illuminating source.

102. Diffusion of Shadows.—Though these properties of the shadows in some instances produce confusion in the resulting negative, in other instances, again, they contribute to rid the field of shadows that are not really desired.

For instance, let it be supposed that the two disks *A* and *B*, Fig. 37, are imbedded in the block *S*, and that it is required to make a Roentgen ray picture of the disk *B* on the sensitive plate *P*. We have here the disk *A* lying directly in the path of those rays that reach the disk *B*, and would naturally confuse the outlines of the latter. To prevent this, the Roentgen ray tube is placed as near the disk *A* as practicable and *B* near the sensitive plate, in order to diffuse the shadows of the former over as large an area as possible, while the shadow from *B* is left in the clear outline. It will be noticed in the illustration that the shadow *A′* is evenly distributed very nearly all over the plate and is, therefore, practically eliminated from the negative.

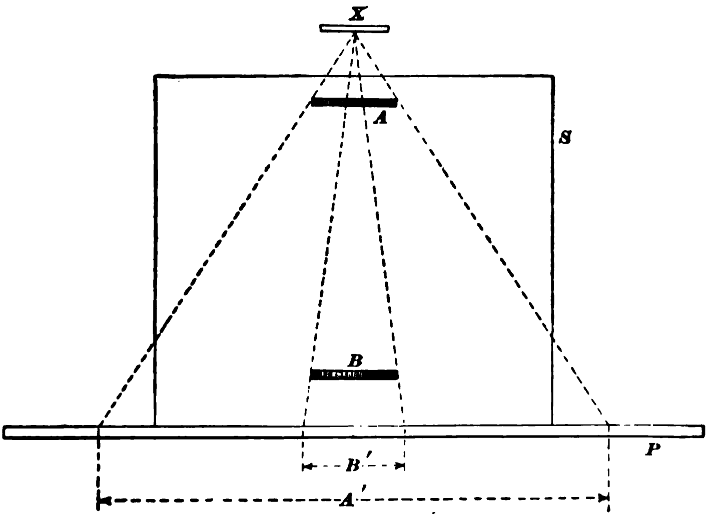


FIG. 37.

103. Separate Objects Equally Defined.—Should it, on the other hand, be necessary to superimpose the shadows of two or more objects on each other in order to show their relative positions, then it is necessary that the distance between them and the Roentgen ray tube should be large in comparison with the individual distances between them and the negative plate. In other words, the Roentgen ray tube should be as far away as possible to obtain shadows of the same sharpness and also of the same size, if both objects are identical in their dimensions. Of course, this distance is somewhat limited by the consequent increase in time of exposure and cannot well be over 4 feet. This combination is shown in Fig. 38, where *A* and *B* are two cylinders of bone imbedded in a block *S* of paraffin that rests on the plate *P*. The Roentgen ray tube anode X sends its rays down to the cylinders, producing the shadows A_1 and B_1, which are seen to overlap each other and to be of the same density and size.

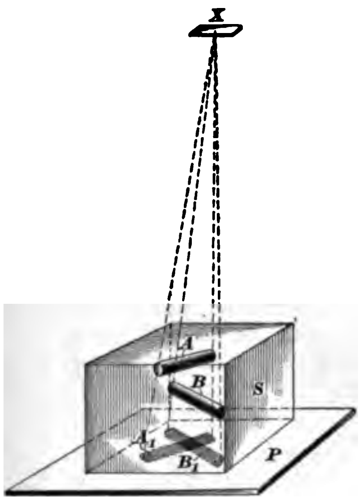


FIG. 38.

104. Other Causes of Diffusion.—There is another cause that contributes to the diffusion of the shadow when an object is too near the source of light. This is founded on the fact that the source from which the light is emitted in a Roentgen ray tube is not a *point*, but a *disk* of measurable dimensions. Usually this disk has a diameter $\frac{1}{32}$ to $\frac{1}{16}$ inch, but sometimes it is considerably larger. In addition to this, it has been observed that the whole surface of the anode is more or less active in sending out a feeble light.

Showing an exaggerated size of the radiating disk *X*, we will observe the effects in Fig. 39. The rays *b*, *b* will give the outlines B_1 of the coin *B*, as before, but in addition to these rays it will be noticed that rays from all over the disk will pass along the edges of the coin, being limited by the rays b_1 b_1. This supplementary illumination will throw the shadow B_2. Both shadows would be of the same density and constitute one shadow but for the fact that the ring-shaped surplus shadow of B_2 receives supplementary rays of light from the outlying parts of the disk X and, therefore, loses in density. By placing a coin A nearer X, the effect is still more exaggerated and we now find that the shadow A_2 covers an area many times that of A_1. The difference between them is, of course, here greatly exaggerated by giving the disk X so large a diameter, but objects placed in a position like that of A will throw shadows, the difference between which will be enough to produce outlines lacking in clearness.

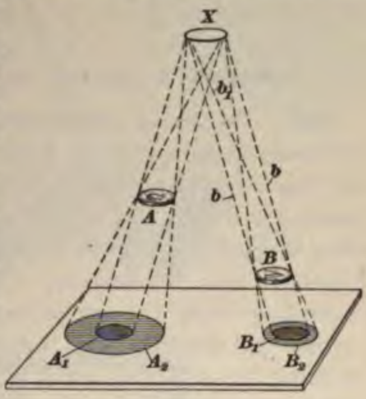


FIG. 39.

Attention may here be called to another phenomenon that tends to decrease the sharpness of a skiagram. It has been found that when the air is exposed to Roentgen rays, it becomes an active agent in diffusing the latter in all directions.

When hard tubes are used, the anticathode takes part in this radiation, and also the walls of the tube and the metallic parts in the same. The supplementary action of these parts increases with the increase in vacuum.

Other surroundings of the sensitive plate, such as the table, the operator himself, etc., act also as additional diffusive agents. These diffused rays are, of course, not as strong as the direct rays, but it may, nevertheless, be supposed that their united action during an extended exposure tends to spread a veil over the whole plate and to lessen the contrasts. For this reason, the method has lately been adopted of limiting the rays solely to the part to be skiagraphed by means of a box lined on the inside with a lead plate of about $\frac{1}{12}$ inch thickness. This box, in which the tube is placed, has already been described. But it may be added that by means of variable apertures, the area of illumination may be limited to just the required extent for covering the parts desired in the skiagram.

DISTORTIVE ACTION OF THE ROENTGEN RAYS.

105. Cause of Distortion.—It is generally known that the shadows shown in the fluoroscope or on a skiagraph show the object represented in a more or less distorted form. The reason for this is not always understood, and, by some operators, it is supposed to be a peculiar property possessed by the Roentgen rays themselves. This is not the case; the rays emanating from the anode proceed along straight lines and outline the shadows with mathematical precision. That the resulting image shows some of its dimensions entirely out of proportion in comparison to others is not the fault of the rays, but an inevitable result from the position of the tube, or, more correctly, that of the anode. The cause of these distortions being known, it is possible to modify them, and, to a certain extent, to avoid them on parts that should be shown in correct positions and outlines.

106. Sun Shadows.—In Fig. 40 (*a*), *A* is a body made up of bars partly parallel and partly at right angles to one another; all bars being of the same thickness. If this plate is laid on a sheet of paper and exposed at right angles to the rays from the sun, then the rays will all be parallel to one another and, also, to the sides of the bars. No shadows will be visible, and if a pencil were made to trace lines along all the sides, it would outline an image that would correspond in its dimensions with those of the body. The sun-rays would trace a shadow entirely identical with that made by the pencil, which in both cases would appear as indicated by Fig. 40 (*b*).

107. Roentgen Ray Shadows.—If we now replace the sun by the anode *X*, as in Fig. 40 (*a*), we find the conditions entirely changed. The source of light is now within measurable distance and will no longer send parallel rays, but such as diverge in all directions. The rays will, therefore, not pass parallel with the sides of the bars, but will either leave both of their sides in shadow or will only illuminate one of them,

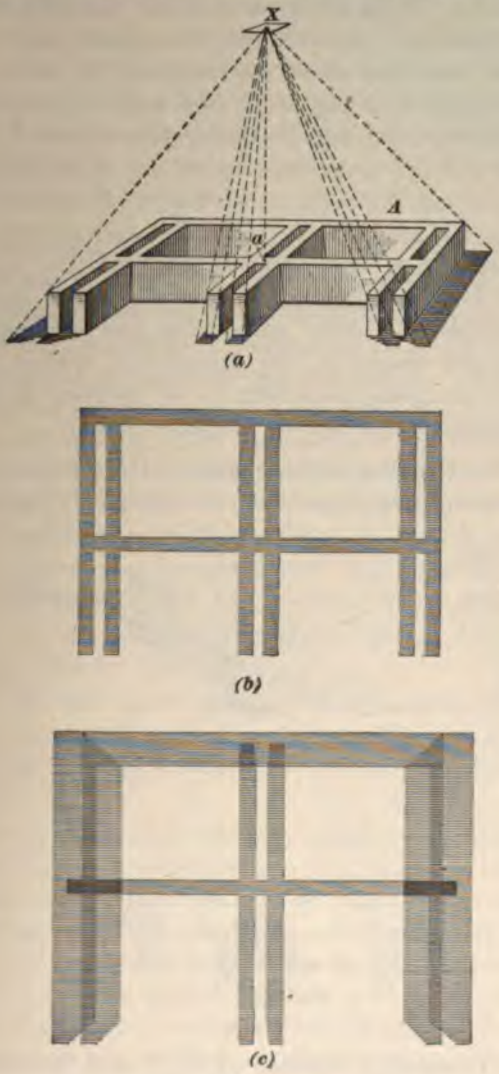


Fig. 40.

consequently shadows will be thrown in all directions, as seen in the illustration. These will grow in extent the farther the parts producing them are removed from the vertical center line Xa. The shadows that thus result are shown in Fig. 40 (*c*). Comparing this figure with Fig. 40 (*b*), we notice a great difference in the length, the width and the thickness of the bars. The only dimensions that are somewhat correct are those belonging to parts situated near the center of the body. In addition to this, we notice that instead of showing the intervals between the bars at the extreme left and right, we find, on the contrary, a deepening and overlapping of shadows. This overlapping would also occur at other places, but has here been partly omitted as not essential. On seeing this shadow, and not having seen the body producing it, an estimate of its shape and dimensions would not be a simple matter.

108. Preventing Distortions.—The method to be pursued to avoid these distortions is illustrated by means of Fig. 41. The anode is represented by X and the whole active field of the rays is outlined by the half-circle $a\,b\,c$. Theoretically, the field should be uniform in strength, clear up to points a and c, but practically this is not the case, it having been

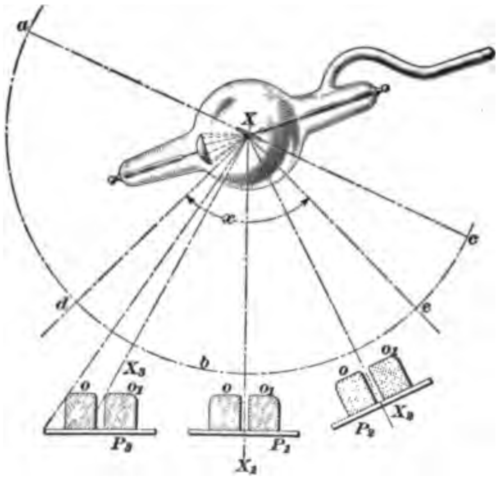


FIG. 41.

found that the field decreases in strength along the radii lying at an angle of 2° or 3° with the radii $a\,X$ or $c\,X$. Nevertheless, this field is not used to its extreme limits for other reasons, one of these being that the rays in certain directions will have to pass through glass for a long distance, as, for instance, beyond the radius $d\,X$. For this reason, the field is usually limited to the part included by the radii $d\,X$ and $e\,X$, or the angle x. The line $X\,X_1$ constitutes the center line of this field.

109. Correct Position of an Object Relative to the Roentgen Ray Tubes.—To receive rays of uniform intensity and to have its shadow free from distortion, any object must be equidistant from the anode X throughout its length and width, or, in other words, to constitute part of a sphere. This being an impossibility in skiagraphy, a compromise has, in some cases, been made by making either the sensitive plate or the fluorescent screen of flexible material, such as celluloid, and bending it in conformity with the arc $e\,b\,d$. In the majority of cases, this is not only impracticable, but also undesirable, and one is obliged to compromise by placing the vital parts in the correct position and let those of less importance be more or less distorted. As the fundamental rule for finding this position, the following may be noted:

Rule.—*The vital part of an object to be skiagraphed should be placed over the center of the sensitive plate and the latter should be at right angles to the line connecting the center of plate with the center of the anode.*

The plate P_1, with the blocks o, o_1, occupies a correct position. An interval has been made between the two blocks to illustrate the importance of the position when bone joints are studied; the angle that the plate occupies with reference to the line $X\,X_1$ being the only one in which the interval will be given its full value. Plate P_2 gives another position in which the size of the blocks and the interval will be correctly skiagraphed. In fact, a plate placed in any position equidistant with plate P_1, inside the angle x, will give identical results. Using a geometrical term, it may be said that a plate placed tangential to an arc having X as center, will give correct skiagraphs. Of course, it is understood that the angle x is spherical and that it, also, will include a similar angle in a plane at right angles to the paper.

110. Incorrect Position.—If, on the other hand, the plate P_1 is moved to the left so as to occupy position P_3, the rule is no longer complied with and distortion will take place. We see that the ray X_3 is no longer at right angles to the plate P_3 as were rays X_1 and X_2. The skiagraph on the former will not give the interval between the blocks, and will greatly distort the shadows.

111. Decrease in Illumination.—In addition to this, it should be remembered that the rays intercepted by plate P_3 are not only farther away from X, and for this reason weaker, but they are at a certain obliquity to the plate, the angle of incidence decreasing with the increase in distance from the center line XX_1. The greater that this obliquity is, the more will the plate approach a parallelism with the rays, and, consequently, the smaller will be the number of rays that are intercepted by the plate. In other words, *the density of rays per unit area will decrease with an increase in the obliquity of the rays.*

112. Position of Large Plates.—When a plate is so large as to simultaneously occupy the positions of the plates P_1, P_2 and P_3, it would be impossible to give it uniform illumination. The outlying parts would be found to be less illuminated than the central part, and a skiagraph would show an underexposure in the former parts. For these reasons, it is always desirable to have the anode as far removed from the plate as possible, if uniformity in the illumination and proportions of the image are required.

Of course, this is not always possible, and then a compromise must be made. The thicker parts of the object, which, if lying some distance from the center would cause more distorted shadows than thinner parts, should be located as near the center as possible. For instance, if a hand is skiagraphed, it would be preferable to have the wrist, as the thicker part, nearer the center position than the fingers. The latter, which decrease in thickness towards their ends, would be less inclined to distort the shadows. And thus, in many other cases, remedies will suggest themselves for avoiding distortions, either by moving the tube or by tilting the object in a position that will allow the rays to act in the most advantageous directions.

LOCALIZATION OF FOREIGN SUBSTANCES IMBEDDED IN THE HUMAN BODY.

113. Fundamental Principles.—It is often of vital importance to determine with exactness the position of a bullet, or similar object, situated somewhere in the human body. There are various methods by which this has been accomplished, but they are all very similar in principle. Reduced to its simplest elements, the principle may be illustrated by means of Fig. 42.

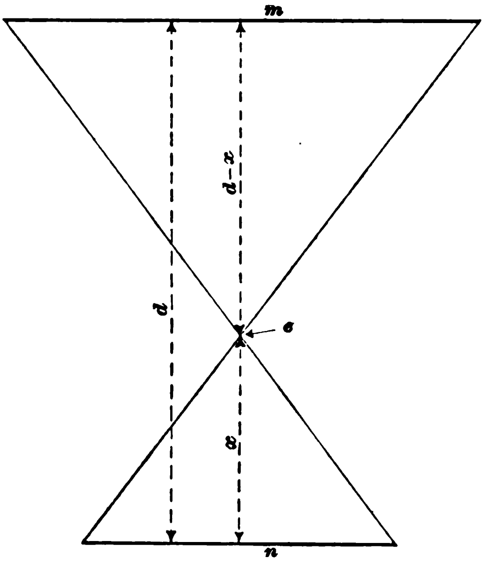


FIG. 42.

If the two parallel lines m and n be connected by means of two lines crossing each other at point e, two similar triangles will be produced in which, according to well-known laws, the distance x and $d - x$ will have the same relation to each other as the lines n and m, or, stated in the form of a proportion,

$$m : n :: (d - x) : x.$$

Consequently,

$$x = \frac{n(d-x)}{m} = \frac{n \times d}{n+m}. \qquad \textbf{(1.)}$$

This means that if the length of the two lines m and n be known, likewise their distance apart d, then it is possible to determine the distance of point e from line n.

EXAMPLE.—When $m = 6$ inches, $n = 2$ inches, and $d = 12$ inches; find x.

SOLUTION.—According to formula **1**,

$$x = \frac{n \times d}{n+m} = \frac{2 \times 12}{2+6} = 3 \text{ in.}$$

The point e is 3 inches above line n. Ans.

114. Practical Example.—In extending the use of this formula to Roentgen ray work, we would, in a general way, proceed as follows, and as illustrated by means of Fig. 43. Let X represent a Roentgen ray tube that is supported on the rod A of stand S in such a manner that it may slide in either direction along the same. L is a block of paraffin containing a bullet B. P is the sensitive plate on which it is required to

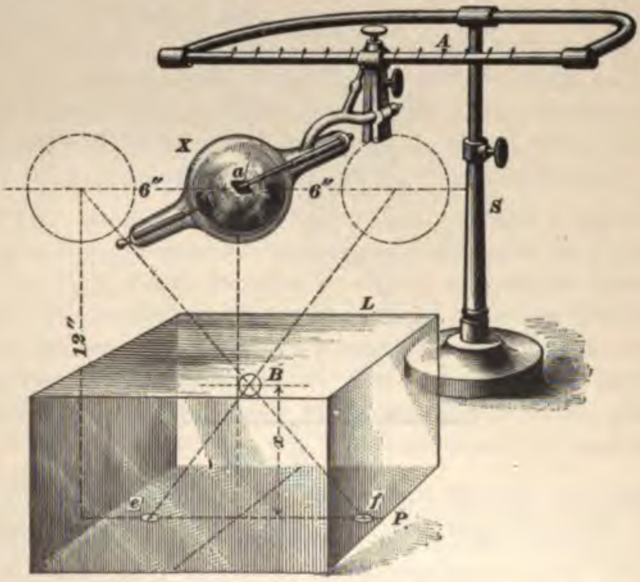


FIG. 43.

picture shadows of the bullet. The first requirement is to mark the center of the plate, and to have this point vertically under the center point of the anode *a*, using, for this purpose, a plumb-line.

115. Marking of Plate and Body.—Various means may be chosen for marking this point. It must be noted that it is not alone a question of marking the outside of the envelope in which the plate usually is placed, but, also, the mark must be of such a nature that it will be visible on the developed plate. This may be done, for instance, by constructing a frame *A*, Fig. 44, provided with an opening *a* across which two wires *b c* are fastened, their point of intersection being, also, the center point of said opening. If, now, the dimensions of the sensitive plate correspond with those of the opening *a*, the frame may be placed over the plate, and the latter will, then, after exposure to the rays, show the shadows of the wire with their point of intersection.

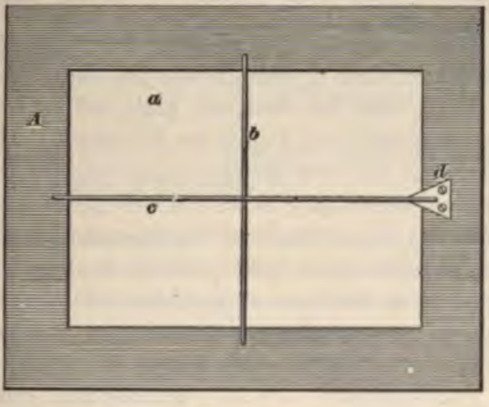


FIG. 44.

It is customary to paint these wires with aniline ink for the purpose of leaving an imprint on the part of the human body with which they come in contact. The mark on the body and on the sensitive plate will then coincide and it will be possible, by means of these points of reference, to ascertain the exact position of the body relative to the plate.

In order to still further determine the exact position of the plate, in relation to the body, a small plate of metal of suitable form may be fastened to the frame, as shown at *d*, Fig. 44, which represents a small triangular piece partly projecting over the plate on which it will leave a mark after exposure. It is thus determined what part of the frame was either to the right or left, as this piece will also leave a mark on the body itself.

In this instance the block has been made of the same dimensions as those of the plate, so as to make the application simpler, and it follows, therefore, that the center of the block will coincide with that of the plate.

116. Position of the Tube.—Next, in order, is the placing of the tube in such a position that the distance between the platinum anode and the sensitive plate will correspond with the distance decided on. Let it be 12 inches. To determine the position that the tube should occupy on either side of the center line, it is customary to have a zero point marked on the rod *A* and to have both halves of the latter marked off in inches. It is then possible to at once read off the distance through which the tube has been moved to either side of the center.

The requirements are now the throwing of two shadows of the bullet on the plate, one on either side of the center line *b*. To accomplish this, the tube is first moved through a chosen distance to the right of the zero point, say 6 inches, then an exposure is made and the tube is moved to the left of zero, either through the same distance, or, for some reason or other, through a smaller or larger one. Let it, in this instance, also, be 6 inches; again an exposure is made. These exposures can either be made on the same plate or on two separate plates. We have now all the data necessary to determine the exact position of the bullet.

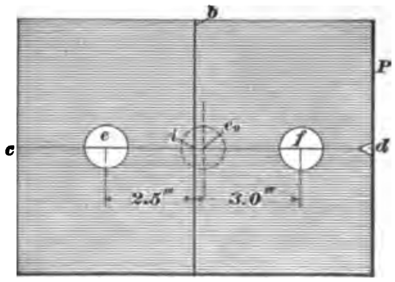


FIG. 45.

117. Appearance of the Skiagraph.—On developing the plate, it was found to have the following appearance (see Figs. 43 and 45): *b* and *c* are the shadows of wires *b* and *c*, *d* that of the triangular plate, and *e* and *f* those of the bullet. It so happens that the shadows of the bullet coincide with the middle line *c*.

118. Distance of Bullet From Surface.—From formula **1**, Art. **113**, the vertical distance from the bullet to the sensitive plate is $\frac{n \times d}{n + m}$; the total motion of the tube is $6 + 6 = 12$ inches $= m$; the distance between the shadows *e* and *f* $= 2.5 + 3 = 5.5 = n$; the height of the tube over the plate $= 12$ inches $= d$.

$$x = \frac{5.5 \times 12}{5.5 + 12} = 3.77 \text{ inches.}$$

From this we learn, then, that the bullet is situated 3.77 inches above the base of the block *L*.

119. Exact Location of Bullet.—It remains yet to ascertain the exact location of the bullet either to the right or left of the line *b*. Various appliances have been suggested for this purpose, consisting mainly of a series of silk threads and weights, by means of which it is possible to reproduce the average length and direction of the Roentgen rays that pass through the bullet, and in this manner to find their point of intersection. By determining the position of the latter, in relation to the center point of the negative, it is possible to find the location of the bullet.

120. Graphic Solution.—It seems, though, that anybody in possession of the most elementary knowledge of drawing could, by means of a drawing-board, a sheet of paper, and a T-square, solve the whole problem in a few minutes, even without using formula **1**, Art. **113**.

Fig. 46 indicates how the problem, illustrated in Fig. 43, may be solved at once and in an easy manner. Let *A* be a sheet of paper fastened to a drawing-board by means of ordinary thumb-tacks, and let *C* be a T-square. Draw the two lines *m* and *n* parallel to each other and at a distance of 12 inches apart, corresponding to that of the tube above the plate. Then draw the line $m_0 n_0$ through the middle of the paper and at right angles to both.

The lengths $m_0 m_1$ and $m_0 m_2$ correspond to the distance through which the tube was moved on either side of zero point m_0. In this example, each of the latter was 6 inches. From the negative, Fig. 45, we find the center of shadow *e* to be at a distance

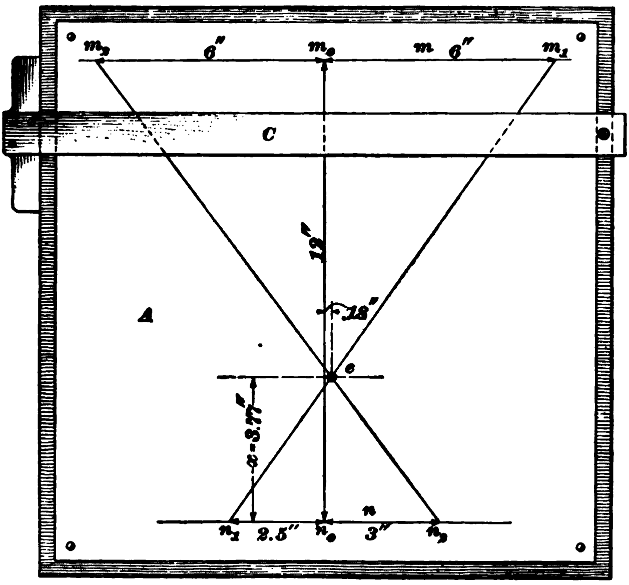


FIG. 46.

of 2.5 inches from center point *i*, and that of *f*, 3 inches from the same. On the drawing, these dimensions are laid off on either side of the point n_0; $n_0 n_1$ and $n_0 n_2$ being, respectively, 2.5 and 3 inches long.

These are all the data required, and it only remains to connect the points $m_1 n_1$ and $m_2 n_2$ to find the point of intersection *e*. Measuring the distance *en*, we will find it to be 3.77 inches, the same as found by means of formula **1**, Art. **113**. But this point is now to the right of the center line at a distance that will be found to be equal to .18 inch, or about $\frac{3}{16}$ inch. After marking off this distance on the negative at e_0, Fig. 45, we know that the bullet is situated 3.77 inches vertically above this point.

121. Another Example.—In this example we have assumed, for the sake of simplicity, that the two shadows of the bullet lie along the line *c*, Fig. 45. This would be a rare coincidence, and in a majority of cases the shadows would be situated in two separate squares, as, for instance, in Fig. 47.

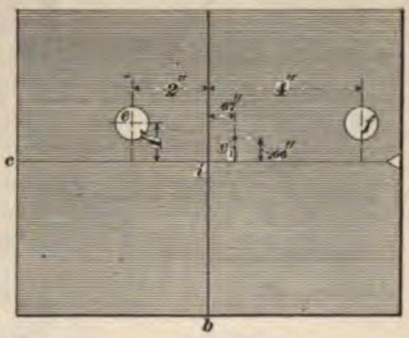


FIG. 47.

We will assume that the distance of the tube from the negative is the same as before and the movement of the former to either side of zero line 6 inches, as before. The method of executing the drawing is also similar, and is clearly shown in Fig. 48. The various points and lines are marked to correspond with those in Fig. 46, thus facilitating an easy comparison. The point e_2 is found to be situated 4 inches above the plate and .67 inch to the right of the center line $m_0 n_0$. To find how far *behind* line *c* the bullet is situated, should in reality require another drawing, with Fig. 48 shown in a side view, but the same drawing can be used for both purposes, thus materially simplifying the whole process. All that is necessary is to lay off the distance $n_0 n_3$, equal to 1 inch, as indicated in the negative, Fig. 47, and to connect n_3 to m_0 with a line. If, now, a line *x* parallel with *n* be drawn through the point e_2, the point of intersection between this line and the line $m_0 n_3$ will determine the point e_1, as shown in the drawing. The distance between this point and the center line $m_0 n_0$ tells us how far the bullet is situated *behind* the line *c* in the negative, Fig. 47. It is found here to be .66 inch. These two distances, .66 and .67 inch, are both laid off on the negative, and locate the exact position of the bullet at the point e_1.

The method of locating here illustrated is capable of a great many modifications, which it is unnecessary here to follow out in detail. The principle will, in the main, be the same, and if once understood, should offer no difficulty in its practical application.

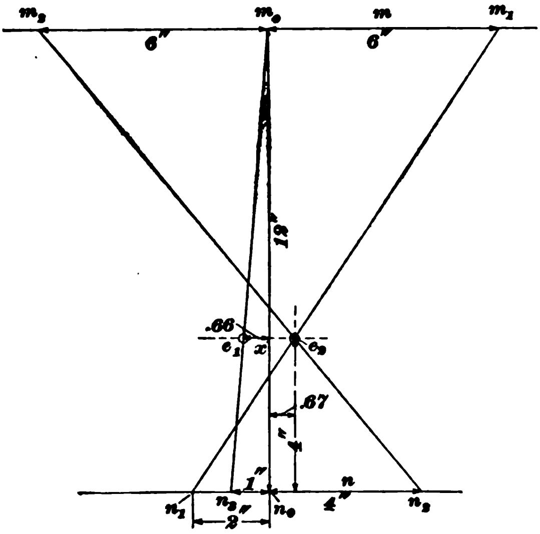
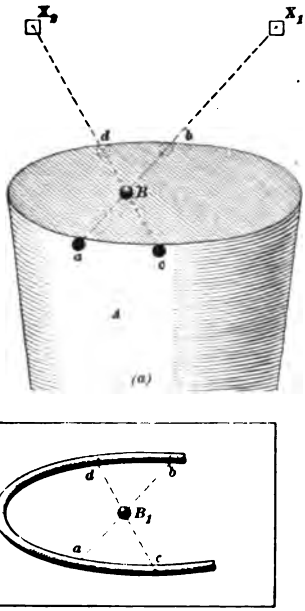


FIG. 48.

122. Other Methods.—In addition to the methods already given, numerous others have been suggested. We will here make mention of one or two that will allow of a great many variations.

Levy-Dorn suggests the following procedure when a foreign body, for instance, is to be located in the thorax. The patient is placed in a chair with a Roentgen ray tube either in front or rear. By means of a fluoroscope, the position of the bullet, if such it be, is ascertained, and the tube is moved until it is in the same horizontal plane as the former. A metallic object, such as a coin or button, is now fastened by means of court plaster in a position so as to cover the shadow of the bullet, as shown at *a*, Fig. 49 (*a*), in which *A* represents part of the thorax, *B* the bullet, and X_1 the anode of the tube. After fastening a similar mark at *b* either the body or the tube is moved so as to occupy a position of X_2 relative to the body. Marks *c* and *d* are then fastened in the same manner. If now a cyrtometer, a lead pipe, or a piece of armored tubing be laid around the thorax, the position of the marks *a*, *b*, *c*, *d* can be marked off on the cyrtometer. When the latter is removed from the body and laid on a sheet of paper, it is possible to trace the curvature on the latter and to mark the four points. When these are connected with each other by lines, as indicated in Fig. 49 (*b*), their point of intersection B_1 indicates the position of the bullet.

A modification of this method consists in using metal rings that move along metallic bands. The rings are adjusted in the manner just described until the bullet is visible through the rings. When the rings occupy the correct position, a mark is made on the body inside each ring, after which the relative position may be ascertained by means of a cyrtometer, as previously indicated. In place of metal marks, it is possible to use a metallic paste made of graphite and vaseline.



(*b*)

FIG. 49.

FLUOROSCOPY.

ITS FIELD AND ADVANTAGES.

123. The main advantage of fluoroscopic examinations consists in the ease and facility with which they can be undertaken at any moment without waiting for a previous exposure and development of a sensitive plate. Also, the possibility of observing the various parts of the body in action and, if any of these parts are injured, to make a preliminary survey of the nature and extent of the latter. On the other hand, it should be remembered that a fluoroscopic image will never have as exact and clear a delineation as a skiagram, in which the diffusing action of the screen is avoided and the accumulative action of the rays is taken advantage of. It is also to be added that the pelvic regions cannot be examined with the fluoroscope, and no information obtained in that manner is comparable with that of a good skiagraph.

FLUORESCENT SCREENS.

124. The Use of Shades.—When the larger sizes of fluorescent screens are used for fluoroscopic examinations, they may be fastened to a wooden frame to facilitate handling. If the dimensions are about 12 inches × 16 inches, they are sufficiently large for observing the largest parts of the body. It may be, under certain conditions, that some parts of the screen are more strongly lighted than others, and that these parts have a disturbing influence on the eyes in preventing them from studying parts situated in denser shadows. In this case it is advisable either to use a screen small enough to cover only the desired part or to use shades of cardboard in which openings have been cut of a size and form more nearly corresponding with the organs under observation, and thus repress the light from other parts. Even when working with the fluoroscope, it is of advantage to use cardboard shades for limiting the view to smaller areas. For instance, when eye cavities are examined, a shade with an opening of 2.5 in. × 3.5 in., or 2.5 in. × 4 in. may be of advantage. This shade may be fastened to the screen by means of hooks.

The same rule, as regards the position of the sensitive plate relative to the tube, holds true also with the fluoroscope.

125. Suitable Tubes for Fluoroscopes. — It has already been said that the tubes for fluoroscopic work must be softer, and that this softness must vary according to the density of the parts observed. Thus a tube suitable for the pelvis would be of little value for the arm or leg, because it does not possess enough differentiation.

126. Skiagraphs Supplemented With Fluoroscopic Examinations.—Sometimes when a skiagraph has been taken of a foreign body imbedded in the muscles of one of the limbs, there is some uncertainty as to whether the object is situated on the upper or lower side of the bones. In such cases, the skiagraph should be supplemented by a fluoroscopic examination. For this purpose either of the following methods may be used:

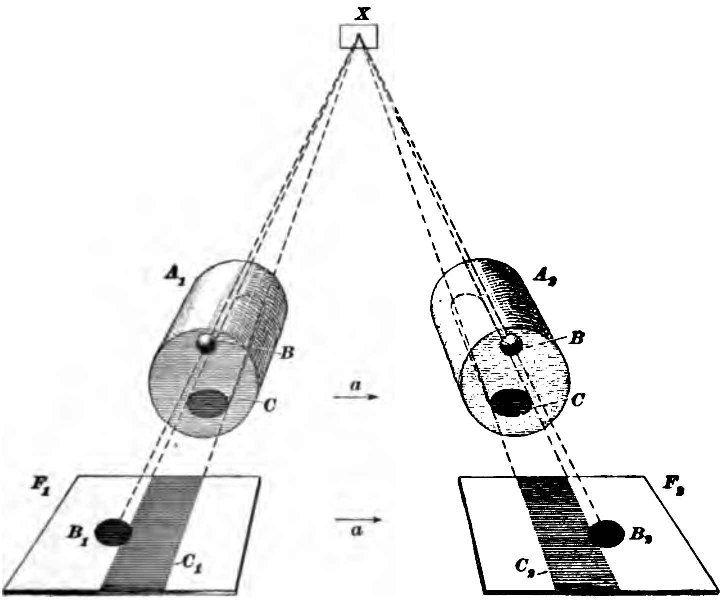
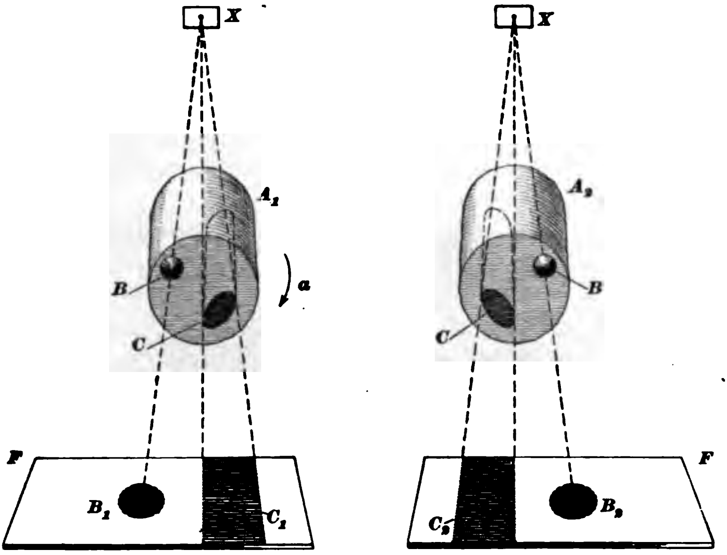


FIG. 50.

In Fig. 50, X is the anode of the tube, A_1 a section of a limb with the bone C and bullet B. F_1 is a fluorescent screen on which are thrown the shadows B_1 of the bullet and C_1 of the bone. On moving the screen and the limb in the direction of arrows a, the limb and the screen will occupy the positions A_2 and F_2, respectively. It is seen that the shadow B_1 has changed from left to right and now has position B_2. From this we deduct the rule, that when a foreign body is situated between the tube and the bone it will move in the same direction as the screen and the limb. When located between the screen and the bone it will move in a contrary direction.

If more convenient, the tube may be moved to the left or right while the limb and the screen remain stationary. Then the bullet in Fig. 50 would move in an opposite direction. Instead of moving the screen and the limb, it may be sufficient to simply rotate the latter around its axis. This method is illustrated by means of Fig. 51 (*a*) and (*b*). The letters in Fig. 50 are again used to represent the same parts. In Fig. 51 (*a*), the bullet appears on the fluorescent screen to the left of the bone C_1, but on rotating the limb in the direction of arrow *a* the bullet appears to move in the same direction as the upper side of the limb, as seen in Fig. 51 (*b*), where the bullet now occupies position B_2. Consequently, it must be situated between the bone and the tube. If below the bone it would, of course, move in the opposite direction.



(*a*) (*b*)

FIG. 51.

THE OPERATING ROOM.

127. It should be the main object to insure stability in the operating room and to provide subdued colors. Vibrations are bound to take place when a motor or motor-vibrator is used, but these should not reach the Roentgen ray tube, otherwise they are bound to interfere with the production of good skiagraphs. It is often that large stands placed on the floor are used for the support of the tube. This is to be avoided, as the vibrations of the tube are greatly magnified, and even footsteps on the floor will affect the tube. If possible, a bracket, somewhat similar to that used by dentists should be fastened to the wall. An extension rod may be inserted in the end and in this manner it would be possible to put the tube in any desirable position. At the same time it would be out of the way and safely supported.

The table should likewise be one with a solid, plane surface, well supported on strong legs, and about 28 to 32 inches high. The dimensions of the top may be about 2 by 7 feet.

A few bags of greater length than width, and filled with sand, have been found very useful in giving support to the body or limbs when the fluoroscope is used or skiagraphs are taken. The bags should not be so full as to make them hard.

For the parts to be skiagraphed, absolute immobility must be secured, and the patient should otherwise be impressed with the importance of keeping the whole body as quiet as possible. If other parts of the body move, then the parts situated over the sensitive plate will unconsciously partake of the motions and prevent the skiagraph from giving details and sharp outlines. For this reason, many operators prefer to strap the parts in question to the table or place heavy articles, such as weighted cushions or books, over the parts. This serves not alone the purpose of preventing motion, but also brings the various parts in closer proximity to the plate.

The room itself should have walls, ceiling, and floor of dark colors, devoid of reflection, if it is desired to work advantageously with large fluorescent screens.

There are two important factors in every successful fluoroscopic examination that the beginner in this line of work must not neglect. We refer to the necessity of working in obscurity and to retinal adaptation. A single test of the importance of these two factors will at once demonstrate their value.

From the researches of *Parinaud*, we learn that after the operator has spent 10 minutes in a darkened room, the retina has become 50 times more sensible to the light emanating from the screen, and that after 20 minutes the sensibility of the retina is 250 times greater than in ordinary daylight. Many physicians have become dissatisfied with the results of their fluoroscopic work, simply because they neglected these two factors.

In order, therefore, to do satisfactory work with the fluoroscope the physician should thoroughly darken the operating room, and he should remain in the same at least 10 minutes before commencing examinations.

SKIAGRAPHY.

INTRODUCTION.

1. **The process of skiagraphy** is based on the photographic effects produced by the Roentgen rays. It means, in reality, the art of making a shadow plan of an object.

One of the first effects observed by Roentgen, while studying the rays, was their influence on photographic plates in a manner similar to that of ordinary light. Since then, the utilization of this welcome means for permanently retaining and recording the invisible shadow thrown on the plate has been used extensively, and is constantly growing in importance.

We say, advisedly, "invisible," as right here is the main difference between skiagraphy and photography. In the latter there is an image visible on the ground glass of the camera with infinite variations in colors and gradations in light. In skiagraphy we see nothing and the image would have been non-existing, as far as humanity were concerned, if the rays were not able to effect chemical combinations and to fluoresce various substances and, thereby, show their presence.

As skiagraphy occupies but a small part of the process of photography, it will be well to limit ourselves strictly to that part that is absolutely necessary for the making of a good skiagraph.

THE SENSITIVE PLATE.

2. **Silver Salts.**—Silver when combined with bromin or chlorin, forming bromid or chlorid of silver, respectively, possesses a certain sensitiveness to light whereby it suffers a chemical decomposition and also partly changes in color. The change in color is more noticeable in the *chlorid* combination, while the rapidity with which the decomposition is

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affected in *bromid* of silver makes the latter more desirable for certain purposes.

To utilize these properties of the silver salts for photographic purposes, they are mixed with a solution of gelatin and spread over the surface that is to receive the image. This may be glass, celluloid, or paper, and these substances, when thus covered, are sensitive to light and constitute sensitive plates, films, or papers. Usually they are referred to simply as *plates*, *films*, or *bromid paper*. By reason of its extreme sensitiveness and the short exposure to light required by *bromid of silver*, this salt is, as a rule, used exclusively for this purpose. It allows exposures to daylight as short as $\frac{1}{1000}$ second, and when lighted by an electric spark, far shorter than this. The image produced on the plate by chemical decomposition is not visible, and a further chemical treatment is required before a visible image will be produced.

Chlorid of silver, on the contrary, while much slower in its action, produces at once a visible image, that can be used, as such, without any additional treatment, except to make it permanent. This salt, when mixed with gelatin or collodion, is used to cover *printing papers*, intended for purposes to be explained farther on.

3. The Sensitive Coating.—The first thing, then, to be considered is the *sensitive plate* of glass that is used almost exclusively in Roentgen ray work. There are a great many plates on the market and some of these are made exclusively for exposures to Roentgen rays. These are given a heavier coating of gelatin than the ordinary plates and have, therefore, a larger amount of sensitive salts distributed over the plate; some have, also, superimposed layers of gelatin of varying sensitiveness. This is for the purpose of giving a denser image and to allow for a greater freedom in time of exposure. The price of these special Roentgen ray plates is greater than that of ordinary plates, such as Seed's 26X and various others, and some operators have not found enough difference between them and those made for ordinary photographic purposes to warrant the additional outlay in price and other inconveniences incident to their use. For beginners, special Roentgen ray plates have some advantages, in that each plate comes in a separate, lightproof envelope, and that it, therefore, can be used at once for Roentgen ray purposes without any further preparation. After exposure, they are, as a rule, sent to some photographer, where they are subjected to further treatment and then returned to the operator for examination.

4. Advantage of Personal Attention to Development.—Other operators prefer to treat the plates themselves from beginning to end. We think this is advisable in all cases where it can be conveniently done, that is, where time and space do not prevent it. The treatment of plates exposed to Roentgen rays demands a different treatment from that given to ordinary plates, and such as a commercial photographer has to learn before he is able to bring out on the plate what should be there. Then again, there are cases where only repeated experiments with a proper combination of time of exposure and suitable development will give the desired results. Results that might be impossible of attainment, if left entirely to the hands of a stranger, not to mention the expense and delay incident to the latter method.

Many physicians think that the time required for this after-treatment is too much, and have also a certain distaste for the work itself, considering it more or less "messy." To them we wish to say, that when done systematically, this work requires very little time and is devoid of any tendency to "messiness"; on the contrary, it demands throughout the most fastidious cleanliness.

THE DARK ROOM.

5. Chemical Action of Various Colors.—An ordinary sensitive plate does not show the same sensitiveness to the various colors. It is found that *yellow*, *orange*, and *red* have much less effect on it than *blue*, *indigo*, and *violet*, while *green* stands midway between these two classes. This insensibility to reddish light is taken advantage of when sensitive plates have to be handled. But it should be remembered that even *red* will in time affect a plate, and that no light is absolutely safe. By a dark room, then, is understood a room that is dark, speaking in a photographical sense, because lighted with a red light, but still light enough to handle with ease and to locate the various objects required for further manipulation of sensitive plates. As so much time is spent in the dark room and so much depends on its practical arrangement, it will repay us from the start to make this so as to fulfil all reasonable requirements.

6. The Location.—The location of the dark room should be such that it is not too hot in summer or too cold in winter. Of the two evils the first is the worst. A dry cellar may answer, and a room boarded up there that may be reasonably warm in winter, if near the furnace. If better places are at disposal, then good ventilation should be the first consideration, preferably one with an outside window. This would have to be light-proof, but might be opened at intervals when no developing is going on, allowing a draft through the room. As regards size, nothing less than 6 ft. × 6 ft. should be selected. Very successful work has been done in small closets, but only under great difficulties, and they should be avoided. The floor should be covered, preferably, with linoleum.

7. The Dark-Room Lantern.—The question of light is important. If electric lights may be inserted, then the problem is easily solved, but frequently such is not the case. Then, either gas or kerosene must be used. If the latter must be used in the shape of a dark-room lantern, as sold by the dealers, care should be had to avoid the small, smoking kind. In fact, a dark-room lantern cannot be too good. In either case, arrangement should be made so that the illuminating source is placed outside the room, or a wooden box built along the wall communicating with the outer air. This box may also have an opening near the ceiling, permitting the hot air in the room to be drawn out, the heated air from the lamp acting as a ventilator. Holes should also be made near the bottom of the box to admit the air necessary for combustion and cooling of heated parts. By having the illuminant placed in this manner, some of the main causes contributing toward dark-room discomforts, that of heat and bad air, are removed.

8. Ventilation.—Additional openings for allowing fresh air to enter the room must also be provided near the floor. Such openings in the lower part of a door or along the wall, with the necessary guards, are shown in Fig. 1. Any of the openings communicating with the outside must be free from direct daylight, and should, if necessary, have additional guards to prevent its entrance. All these openings should be covered with dull-black paint.

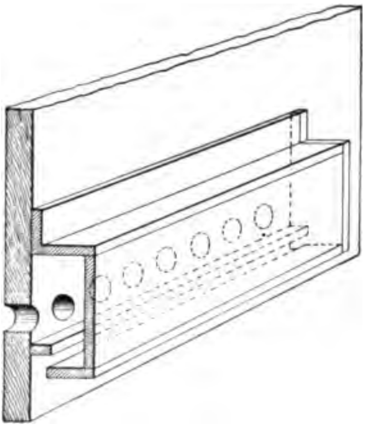

FIG. 1.

9. Regulating the Illumination. — Either of the illuminants should be provided with means that permit them to be regulated from outside the enclosing box. A window made to open inwardly is placed in front of the illuminant, and if gas or electric light is used, then the window glass must be of a dark-ruby color. If a dark-room lantern is used, this glass is furnished with the same. As the direct glare of the red flame is unpleasant, it is well to paste a sheet of orange-colored paper outside the glass, that is, toward the operator, which has the effect of diffusing the light; at the same time it acts as an additional safeguard against actinic light. In addition to this there should be a movable shade hinged to the upper part of the window with arrangements, such as a chain, for fastening it at any suitable angle. The eyes will then not be annoyed by direct light from the lamp, and it is also possible to keep the light away from the developing trays. Provisions should also be made so that the dark-room door may be locked from the inside; this is to prevent an unexpected opening of the door with a possible ruin of valuable plates.

10. The Sink.—Directly in front of the lamp is the sink and the water supply. The height of the sink above the floor will depend on whether the operator prefers to sit or stand; if the former, then about 30 inches, otherwise 45 inches. Its dimensions should be 3 feet square and 6 inches deep. It may be of wood and lined with lead or zinc. Over one part of the sink should be a grating on which the various developing trays may be placed, and alongside the sink a table on which developers may be mixed or other chemical manipulations performed. Above the table may be shelves for the storing of bottles. These shelves should not be too deep, as it is inconvenient to have bottles standing in several rows. Under the sink may be a series of racks for the storing of trays, etc. Adding a sponge and towel for general use will about complete our dark-room outfit.

THE EXPOSURE.

11. Preparation of the Plate.—In case the Roentgen ray plates are already inserted in light-proof envelopes, then the dark room is not needed before an exposure can be made. If ordinary plates are used, then some preliminary work must be done in the dark room. These plates come in pasteboard boxes, whose covers are sealed light-proof. Take the box to the dark room, put it face down and feel with the thumb nail along the bottom edge. A depression will be felt between the cover and the side and a knife should be inserted here and slid along the edge, thus cutting the strip of sealing paper. Repeat this operation along all four sides, clear to the corners. Now turn the box over and, grasping the sides of the cover, gently shake the box up and down, when the cover will come off. They fit, as a rule, pretty tightly and care must be taken not to damage the sides of the box, as this would make it pervious to light and possibly spoil the plates when daylight is permitted to enter the room. Most boxes have an additional box inside the outer one, and often we find each six plates laid in double envelopes of black paper. One plate should now be removed carefully in a manner so as not to scratch the surface of the next one, as they are usually laid in pairs facing each other. Having obtained the plate, it is important to ascertain which is the sensitive side. When the lamp is lighted, this is easily ascertained by noticing the reflection of the light, the rear side showing a bright image and the sensitive side only a dull one. In the absence of any light, the feeling alone will tell which side is covered, but care should be taken never to touch the plate except near the edges. The perspiration on the fingers is liable to leave marks that will later on show as bare spots and spoil an otherwise perfect plate.

The plate may now be inserted in suitable envelopes made of black and ruby-colored paper, one envelope placed inside the other. These may be obtained ready-made. One must be sure to always insert the plate in the same manner, so that never any doubt exists which side is the sensitive one, because when exposed to the rays the sensitive, or film, side is always turned toward the tube.

The use of a double envelope to prevent the light from reaching the sensitive plate is satisfactory for most cases. When heavy parts of the body are resting on plates of large dimensions there is some danger of their being broken. In such cases it is of advantage to use what is termed a *plate-holder*, a shallow box of wood with a cardboard cover hinged to it. The plate is laid in this holder and placed under the body with the thin cover uppermost, that is, between plate and tube. Plates of smaller dimensions can also be used in this holder, then supplementary mats or kits must be inserted to keep them in a central position. The outlines of the diverse plates that may be laid in the holder are, as a rule, marked on the outside of the cover. This is to insure a correct position of the object relative to the plate. When fluorescent screens are used to shorten the exposure they are, as a rule, fastened to the inside of the cover.

In storing dry plates, they should be kept in a cool, dry place, for heat and moisture will spoil them.

The Roentgen rays will act through a considerable distance, even through the walls of a room. It is therefore important that a sensitive plate is not in the neighborhood of an active tube and it should never be brought into the operating room before everything is ready for the exposure. At other times the plates should be as far away from the tube as possible, and are preferably stored in a heavy zinc or iron box.

12. Testing Intensity of Rays.—The intensity of the rays is usually tested by letting the rays penetrate one hand held against the fluoroscope. Various other methods have also been suggested, which are mostly founded on the ability of the rays to penetrate metal plates of varying thickness. One device of this kind consists of a wooden frame having eight sections of aluminum plates that vary in thickness from 1 up to 12 millimeters. They may be marked in any suitable manner, as, for instance, by drilling a series of holes in each plate corresponding to its number and then fill these with lead wire. These will then show as dark spots. Holding the frame against the fluoroscope and finding how many of the plates are visible will enable one to determine the penetrating capacity of the tube.

13. Protection of Plate.—The sensitive plate must be so placed that the coating of gelatin is on the upper side, that is, facing the tube.

In case the exposure has to go on for some length of time, and preferably in any other case, it is of advantage to place some material between the body and plate to prevent any effect of heat and perspiration reaching the latter. A piece of silk or blotting-paper or a thin sheet of celluloid laid on the plate will answer this purpose.

An aluminum plate is sometimes laid over the sensitive plate and connected to the earth. This is to prevent static charges collecting on the glass. Such charges would, when the plate is removed from its envelope, be inclined to jump across the plate and leave marks that would show in the developed plate, and have an appearance somewhat like blood-vessels or the branches of a tree. A piece of cardboard coated with tin-foil and provided with an aluminum chain of sufficient length will also answer the purpose.

14. Intensifying Screens and Double-Coated Plates.—It has been found that the sensitive plate utilizes only a small part of the rays, the remainder passing unhindered through the same. Various means have therefore been suggested for making plates of a higher efficiency. With this end in view films or plates have been provided with sensitive coatings on both sides, so that the rays, after acting upon the upper side, proceed through the glass or film and also act on the lower side. After development these skiagraphs will show two superimposed images, thereby greatly strengthening the total density. By using such plates the exposure may be greatly reduced. In other instances, several layers of bromid papers, such as mentioned in Art. 48, have been used. It is then possible to simultaneously produce a number of copies without the use of a negative.

Intensifying screens have been frequently used for the purpose of shortening the time of exposure. Hitherto, this reduction in time has mostly been at the expense of clearness, caused by the granular nature of the screen. But lately some screens have been made by Kahlbaum, in Berlin, and others, that seem to overcome this difficulty. They are made of tungstate of barium and have so fine a grain that no lack of definition is noticeable in the photographic image. The screen is placed in contact with the film and the whole is placed so that the rays must go through the screen before they reach the sensitive film. When using such screens, Donath, Berlin, has been able to reduce the time of exposure for a shoulder-joint down to 2 seconds, and for the pelvis to 20 seconds; he secured in each case skiagraphs of clear definition and details.

15. Effects of Variation in Distance on Exposure. If two skiagraphs are taken of the same object, but at different distances from the tube, then a longer exposure will be required for the position that is the farther from the tube. This increase in exposure is not proportional to the distance, but to the square of the same, following the same law as exposures to ordinary light. That is, if one object is at 8 inches distance and the other at 16, the latter will require an exposure 4 times that of the former.

An example will show the application of this rule. Let it be supposed that the correct time of exposure for a hand has been found to be 20 seconds at a distance of 8 inches. It is required to find the time for the same object at a distance of 12 inches. It is customary to select the hand as an object for estimating unit exposure; let this unit time be signified by the letter t_1.

Therefore, t_1 = unit exposure;
t_2 = exposure to be determined;
d_1 = tube distance for t_1;
d_2 = tube distance for t_2.

We have then the proportion $d^2_1 : d^2_2 :: t_1 : t_2$,

or,
$$t_2 = \frac{d^2_2 \times t_1}{d^2_1}.$$

On inserting the above values,
$$t_2 = \frac{12^2 \times 20}{8^2} = \frac{144 \times 20}{64} = 45 \text{ seconds.}$$

16. Effects of Density and Depth on Exposure. Besides distance, there are two other elements that decide the length of exposure, *density* of material and *thickness*, or *depth*, of the object. An increase of either of these factors increases the length of exposure in the same proportion. It is preferable to estimate the effect of them in conjunction with each other as a total resistance to the rays. Let this resistance be termed *R*. To facilitate calculations of exposure, various attempts have

TABLE 1.

RELATIVE RESISTANCE OF PARTS OF THE HUMAN BODY TO ROENTGEN RAYS.

	R		R
Hand (central part) .	1	Thorax	3–4
Lower arm	1.4	Sternum	3.8
Elbow-joint . . .	1.5	Foot	1.4
Upper arm	1.8	Tibia	1.8
Shoulder-joint. . .	3	Knee	2
Clavicle	2.7	Thigh	3–5
Neck	3	Hip-joint	5–6
Skull	4.5	Pelvis	8–10

been made to find this resistance for different parts of the human body. The preceding table by Donath gives the relative resistances of the parts named when the central part of the hand is taken as a unit resistance.

17. Calculations of Exposure.—This resistance R may be used in combination with the other values t_1, t_2, d_1, and d_2 to estimate the time of exposure. But these calculations must be considered as a guide only; variations will occur, depending on changes in the vacuum of the tube that are likely to take place at any moment during prolonged exposures. Those who are adverse to any kind of calculations may use the above table simply as a guide for the relative lengths of exposures.

The formula just quoted will, when the value R is included, assume the following form:

$$t_2 = \frac{t_1 \times d^2_2 \times R}{d^2_1}.$$

As examples for applying this formula, let the following be taken. A trial exposure of the hand showed that 20 seconds was required for a distance of 10 inches between the tube and plate. It is desired to take a skiagraph of the thorax and to increase the distance to 16 inches. Required to find the time of exposure: $t_1 = 20$ seconds; $d_1 = 10$ inches; $d_2 = 16$ inches; $R = 4$.

$$t_2 = \frac{20 \times 256 \times 4}{100} = 205 \text{ seconds, or 4 minutes 25 seconds.}$$

Required to take a skiagraph of a pelvis and to increase the tube distance to 24 inches. Using the previous data as a basis, we have $t_1 = 20$; $d_1 = 10$; $d_2 = 24$; $R = 8$.

$$t_2 = \frac{20 \times 576 \times 8}{100} = 922 \text{ seconds} = 15 \text{ minutes } 22 \text{ seconds.}$$

THE DEVELOPMENT.

18. Main Principles.—After exposure, the envelope is removed to the dark room and preparations made for developing the plate. By *development* is meant the bringing out of the latent image, or in other words, by a chemical solution, to reduce the silver salts acted upon by the light. Those parts most strongly affected by the light will also be most affected by the solution, while those not acted upon by the light will remain chemically inactive. The effect of the solution is to make those parts on which it reacts the strongest more or less opaque. Consequently, the resulting image will be reversed in so far as the brightest parts of the virtual image will appear the darkest, and it is therefore called a *negative.*

As the action of the light on the plate is of a cumulative nature, the time of exposure must be regulated according to the intensity of the light.

19. The Developer.—When the operator gets more familiar with the developing fluid, or *developer*, he will prefer to compound it himself. For a beginner, it will be best to procure the chemicals in tablet form ready for mixing with water. Carbutt and others make such suitable for Roentgen ray plates. The tablets may be mixed with water in quantity and kept in a large bottle, or only enough dissolved for immediate use. The former method is preferable, if a great deal of developing is done.

20. Insertion of Plate.—The developer is poured into a developing tray of a size corresponding to that of the plate, not larger, as this results in a waste of developer. When the plate is laid into the tray with the film side up, it is important that the developer should cover at once the whole plate, otherwise stains and streaks will be the result. One way of avoiding this is to tip the tray sidewise so that all the developer recedes to one side, then lay the plate in the bottom and quickly tip the tray to the other side and, also, lengthwise until the whole surface has been wetted. If the plates are very large, use in addition a swab of absordent cotton and rub it quickly, but gently, over the places that are not at once covered by the developer. Or, the plate may be previously soaked in water. For a 5″ × 7″ plate, about 4 ounces of developer is needed to properly cover it, and other plates in proportion.

When small films are used instead of plates, as, for instance, in dental work, Doctor Custer suggests the use of an ordinary porcelain teacup instead of a tray. It will be found that the film is too small to handle conveniently without destroying the edges in its manipulation, if attempts are made to keep it straight. Enough developer is prepared to more than cover the film, and the cup is continually shaken during development.

21. Appearance of Image.—If the plate is well exposed, an image should begin to appear on the plate in 15 to 30 seconds, depending on the developer. The tray is given a gentle rocking motion, at least during the first part of the development, to insure an even action of the developer. The time required for reaching a sufficient density in the negative may vary from 4 to 20 minutes, sometimes even longer. It is not necessary to watch the tray during all this time; it may be covered over with some opaque material and left to itself.

22. Length of Development.—The development of a Roentgen ray negative must be carried on much farther than an ordinary negative. Those representing the denser part of the human body should be developed to such a density that the whole negative appears uniformly black all over. It will then, after fixing, show the necessary gradations in density. As long as the negative has not reached this density, it should be retained in the developer and the action of the latter continued until the desired density is attained. In some plates this will be indicated by the appearance of the denser parts of the image on the back of the plate, while in others the desired density may have been reached before this image is visible. Plates of different makes show varying characteristics in this respect, depending somewhat on the thickness of the film.

23. Quick or Slow Development.—Sometimes a weak solution and a slow development bring out more details than a strong solution and a quick development. At times a development extended through a period of 3 hours has been found to give negatives rich in detail. In general, development should be slow and aim at hardness. If too hard a tube is used for thin objects, such as a hand, overexposure may result of a nature that is difficult to correct in development. If a soft tube is used for the same object, overexposure to the extent of 10 to 12 times may have been made, and still a good skiagraph be obtained. This it will be well to remember.

24. Treatment During Development.—During development the plate should not be examined too frequently and should preferably be in the dark altogether, that is, the developing tray should be covered over. When an examination is required, it is done by holding the negative 10 to 12 inches from the ruby light and with the *film* side turned toward the light. The outside of the film completes its development before the inside and is therefore less sensitive to light. Very dense negatives cannot be examined in this manner, but can only be judged by the darkness of the reflected image.

25. Multiplying Factor.—It is also possible to determine the required time for development by means of the so-called *multiplying factor*, or simply *factor*. The time of development is divided into two periods that bear a certain relation to each other. The first period is reckoned from the moment the plate is under the developer until the first sign of an image is visible. By noting this time on the watch and multiplying the time with the corresponding factor of that developer, we find the time required for the second period, which completes the development.

Let the developer be hydrochinone and the first period 30 seconds. The factor for this developer is 5½. Multiplying 5½ by 30, we have 165 seconds, or about 2¾ minutes.

Some of the factors for the leading developers are as follows: Metol, 28; hydrochinone, 5½; metol and hydrochinone combined, 13. If, by experience, the factor is found too small or too large, the remedy is obvious.

26. Contrast in Development.—The temperature of the developer should be between 60° and 70° F. If colder, the action is slower, and if warmer, the image will lack in contrast and may be "foggy." The latter expression means that the plate has assumed a grayish tint all over. It should be remembered that there is quite a difference between an ordinary negative and that produced by Roentgen rays. The first is full of light and contrast, and sharply outlined figures, while the latter is only made up of transmitted light, lacking in contrast and, therefore, inclined to appear flat. Everything should, therefore, be done in the development to produce contrast.

27. Removal of Developer.—When the development has proceeded far enough, the plate is removed from the tray and either inserted in a tray containing fresh water, or held under the tap for half a minute while a gentle stream of water is removing the developer, after which it is ready for the fixing bath.

28. Theory of Development.—For those who later on prefer to compound their developer themselves, a few explanations are here added concerning its composition and action.

A developer consists of four elements:

1. The reducer (metol, hydrochinone, pyro, etc.).
2. The accelerator (carbonate of soda or potassium, etc.).
3. The preserver (sulfite of soda, etc.).
4. The retarder (bromid of potassium, and some others).

The proportions in which these various elements are mixed, so as to make a suitable developer, depend on diverse conditions. For instance, a plate with a thin layer of gelatin of high sensitiveness demands a different developer than a slow plate. An object in which white predominates requires another development than that given an object with subdued colors. Quickly exposed plates differ in development again from plates submitted to an extended exposure, as do underexposed from overexposed plates.

If proper attention is not paid to these variations in development, faulty negatives will result. These failures may be caused either by *overexposure* or *underexposure*, or by *overdevelopment* or *underdevelopment*. Too warm a developer or fixing bath may, also, spoil a correctly exposed negative. The signs by which these various faults may be recognized, and the remedies, are usually found in the instructions enclosed in any box of plates and it will, therefore, be superfluous to repeat them here.

As a guide in regulating the development, the following table may be used:

TABLE 2.

	Reducer.	Accelerator.	Retarder.	Water.
To accelerate development .	Normal	Increase	Normal	Reduce
To retard development . .	Normal	Reduce	Increase	Increase
To increase contrasts . .	Increase	Reduce	Increase	Normal
To reduce contrasts . . .	Reduce	Increase	Reduce	Increase

In the above table it is supposed that a developer is used in its *normal* condition for a correctly exposed plate, and that the proportions of its various ingredients are increased or decreased, as the conditions may require.

29. Formulas.—Of the many formulas that have been suggested for Roentgen ray negatives, only three will be quoted here as having been used with some success by various workers.

Metol	90 grains.
Hydrochinone	30 grains.
Water	24 ounces.
Sulfite of soda (crystals) . . .	3 ounces.
Carbonate of soda (crystals) . . .	13 drams.
Add water to make	32 ounces.

For normal exposure: 3 ounces of developer, 3 ounces of water, 1 dram of 10 per-cent. solution bromid of potassium.

For underexposure: 2 ounces of developer, 2 ounces of water, 15 minims or 10 drops of 10 per-cent. solution bromid of potassium.

For overexposure: 2 ounces of developer, 4 ounces of water, 1½ drams of 10 per-cent. solution bromid of potassium.

Another formula that has been found very satisfactory is the following:

Metol	80 grains.
Hydrochinone	45 grains.
Sodium sulfite (crystals)	640 grains.
Sodium carbonate (crystals)	640 grains.
Add water to make	20 ounces.

In the latter formula there is a greater proportion of hydrochinone which seems to be of advantage if density is desired.

When great contrast and intensity is desired, the following formula, by Cramer, works very well:

No. 1.

Hydrochinone	½ ounce.
Sodium sulfite (crystals)	3 ounces.
Bromid of potassium	¼ ounce.
Distilled water	25 ounces.

Dissolve in warm water and let cool before using.

No. 2.

Sodium carbonate (crystals)	6 ounces.
Water	25 ounces.

Mix Nos. 1 and 2, equal parts, for use.

This developer is also good for overexposed plates. By varying the proportion of No. 2, either more or less contrast may be obtained, a decrease of sodium carbonate producing more contrast, in particular if the plate is overexposed. This developer works with great rapidity, 3 to 4 minutes being sufficient for maximum density.

When, in either of the above formulas, sodium sulfite or carbonate has to be used in a powdered form, instead of crystals, then one-half only of the stated quantity must be used.

Whenever a developer has been found to work satisfactorily, it is advisable to retain it and to get familiar with it in all its variations. This also holds true with regard to plates. To change constantly from one to another, as they happen to be recommended, is very poor policy. It is not an easy matter, in any case, to make correct exposures, and requires some extended experience, but by constantly introducing new and unknown elements, variations in exposure and development are required that will take time to master. In the meantime, resource must be had to guessing with all its uncertainties and disappointments.

30. Overexposure and Underexposure.—To make a distinction between overexposure and underexposure is not very difficult when ordinary negatives are considered. With skiagraphs the conditions are somewhat different, because depending on several variable factors. If the tubes used were always operating with the same vacuum and the same intensity, much of the difficulty would be obviated, but as both of these factors are very variable, the problem is not an easy one.

In an ordinary negative an *underexposure* is recognized by a lack of detail in the shadows, that is, in those parts that have received a smaller quantity of light. They have not had time enough to impress the sensitive plate, and will, therefore, leave more or less blank places where gradations of light and details of structure should otherwise have been visible. When such plates are submitted to the influence of the developer the image will appear slowly, and the parts most highly lighted will appear first. Those in the shadow will delay their appearance or perhaps not come up at all or only in very faint outlines. Such negatives show too much contrast, being made up of transparent shadows and strong high lights with few gradations.

If an *overexposure* has taken place the negative gives an impression of "flatness" and shows lack of contrasts. Here the parts situated in the shade have been given too much time to affect the sensitive plate, therefore giving plenty of detail in the shadows. The result is that little difference is found between highly lighted and shaded parts. When such a plate begins to develop, the image will appear almost simultaneously all over the plate, and will thus denote the fact that an overexposure has occurred.

In skiagraphs we have, to begin with, no reflected, but transmitted light. As a consequence, there does not exist such contrasts as in ordinary negatives, but rather a certain sameness of tone. Overexposure can therefore not be judged by ordinary standards. When, for instance, a skiagraph is taken of deeper tissues, where there is an almost total absence of contrasts, then the image, during the development, is liable to appear simultaneously all over the plate. In this instance it would not necessarily be an indication of overexposure.

Then, again, an overexposure may have taken place and still the denser parts left without any structural details. This would, for instance, be the case if a soft tube were skiagraphing a body composed of more or less transparent parts. It would be able to overexpose the transparent, but unable to affect the shadows of the dense part. Such a skiagraph would then have the appearance of being underexposed, while in reality with that particular tube an overexposure may have been made.

On the other hand, a hard tube may have been used for an object of small depth, with the result of producing a skiagraph without contrasts. Here the general appearance would signify overexposure, but even a greatly reduced exposure would fail to produce the proper contrasts between the constituent parts. The reasons for this have been given in Arts. **93** and **94**, *The Physics of Roentgen Rays.*

If a medium-hard tube is used for the hand and the exposure is correct, the fleshy parts would appear first and then the bones with their structural details.

Referring to skiagraphs, it may in general be said, that when the image appears slowly and with difficulty, showing only general outlines and being rather transparent, then an *underexposure* has been made.

A *correctly* exposed plate will let the various parts appear in the order of their relative transpariencies, showing good contrasts and plenty of details.

When an *overexposure* has occurred then the image will appear quickly and in a monotonous tone, but will also rapidly disappear again in the general darkish veil which soon will cover the whole plate.

In predetermining the correct exposure one of the self-regulating tubes is of great assistance. One has then to deal with rays of a certain standard penetration, that may be adjusted once and for all for objects of a given depth. After some comparative exposures have been made it is at once possible to tell when an underexposure has been made by not finding details in certain parts which ordinarily should show such. Or, if at other times, the skiagraph shows too much density in parts that should be more transparent, then either an overexposure or overdevelopment has been made.

The remedies for overexposure and underexposure have been given in Arts. **28** and **29.** It may here be added that the tank development, mentioned in Art. **31,** has shown itself efficient in removing the effects of both an overexposure and underexposure.

31. Tank Development.—The method of developing a number of plates in one box, called *tank development*, has been used for skiagraphs with good results. When it is convenient to give a negative 12 hours or more in which to complete its development, and thus to bring out everything possible, tank development is to be recommended. The difference between this and ordinary development consists in diluting the normal developer by the addition of water, making the final bulk 6 to 8 times that of the original, so that it contains about ½ grain of developer per ounce of solution. This solution is poured into a box similar to the fixing box, described in Art **34,** when as many plates may be inserted as the number of vertical grooves will allow. The rate at which the development proceeds is, of course, greatly reduced and, in general, it is found that plates inserted in the evening will be ready next morning. Should the negatives show lack of density, then they may receive an additional development in a normal developer.

It is best to have a tank or box that is used for nothing else but development though some operators leave the plates in this box and let them undergo the successive operations of fixing and washing without any further handling. In that case, the developing solution must be poured out and the tank cleaned by three or four changes of water, after which the fixing solution is poured in. Finally [illegible] is displaced by the water for the final washing.

FIXING.

32. Hypo Fixing Baths.—By **fixing** is meant the removal of all the silver salts unacted on by the light, thereby greatly reducing the density of the negative. This must always be taken into account when a certain density is desired. The main constituent of the fixing bath is hyposulfite of sodium, commonly called hypo. An ordinary hypo bath consists of 1 pound of hypo and 2 quarts of water. Part of this is poured into the fixing tray and the plate immersed, film side upwards.

Care should be taken to leave the negative in the fixing bath a sufficient length of time in order to insure the complete removal of the sensitive salts that have not been acted on by the rays. For ordinary plates it is sufficient to leave them in the bath from 3 to 5 minutes after the white image on the back has entirely disappeared. For Roentgen ray plates this is not enough, because they have much thicker films, and the action of the fixing bath, consequently, is much slower. It is, therefore, better to leave them in the bath an additional 15 minutes after all the white has disappeared from the back of the plates.

33. Acid Fixing Bath.—It is not advisable to use the above solution more than once, but if the so-called *acid fixing bath* is used, the same solution may be used for over half a year or until its action begins to grow too slow. It is made up as follows:

No. 1.		No. 2.	
Water . . .	96 ounces.	Water . .	32 ounces.
Hypo . . .	2 pounds.	Chrome alum .	2 ounces.
Sulfite of soda .	4 ounces.	Sulfuric acid .	¼ ounce.

The acid should be slowly added to No. 2. Pour No. 2 into No. 1 under vigorous stirring. This bath has the effect of hardening the film.* When the action of the bath begins to grow too slow it should be thrown away.

34. Fixing Box.—Instead of pouring the fixing solution into a tray and, after it has been used, pouring it back into the bottle, it is more convenient to use a *fixing box*, usually made of hard rubber and provided with grooves along its sides. The whole solution is poured into this box and kept there, and whenever one or more negatives are to be fixed they are simply slid down in the grooves and left there until ready.

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*Seed and others mix the ingredients of this bath in the right proportions and put them up in boxes ready for dissolving in the proper amount of water.

35. Importance of Cleanliness in Dark Room. Cleanliness in the dark room is of the utmost importance. For instance, it will not do to put the fingers into the fixing bath and then back into the developer and handle the plate, for by this procedure one is running the risk of spoiling the plate by causing the production of transparent spots.

It should be an invariable rule to wash the fingers and dry them immediately after they have been in contact with the hypo solution. Likewise the fixing solution should not be permitted to drop upon the floor while the negative is being examined. Such drops will dry, and the powder resulting from them will eventually get into the air and unexpectedly descend in the most undesirable places.

Then, again, the developing tray should never be used for fixing, or vice versa, but one tray should be devoted to each of the various operations. Graduating glasses, scales, etc., should be absolutely free from foreign substances before they are put away.

WASHING AND DRYING.

36. Final Washing.—After the negative has been fixed, it is ready for the final operation, that of *washing*. The best apparatus for this purpose is a washing box made of zinc, which may be bought from any dealer. They have an inside loose frame in which the negatives are placed side by side, and may thus be simultaneously lifted either into or out of the box. In the lower part is a short tube over which a rubber tube may be slid and connection made with a faucet. A stream of water will then pass through the box in an upward direction and flow out through a short spout near the top. As the hyposulfite is heavier than the water, it will sink down if the current does not constantly bring it to the surface and remove it.

An ordinary plate, thinly coated, will have the hypo removed from it in about ½ hour; more thickly coated plates require 1 hour, and Roentgen ray plates require 2 hours. If the hypo is left in the film it will, in time, cause spots, and spoil the negative. The length of time here given for the final washing is that needed to insure absolute permanency. In cases where it is simply a question of a single inspection or of keeping a plate for a couple of years, then it may be sufficient to cut the washing of a Roentgen ray plate down to 45 minutes. Too prolonged washing in warm weather is not advisable, as it may result in frilling and partly dissolve the gelatin.

After washing, it is of advantage to slide some absorbent cotton gently along the film to remove any substances that may adhere and also the surplus water. This will accelerate the subsequent drying.

The above-mentioned box is suitable only for negatives of a smaller size. For larger sizes it may do to empty the fixing tray of its solution and to complete the final washing in this tray. The latter may be set in the sink and slightly elevated at one end so as to compel the stream of water, flowing into it from the faucet, to pass along the whole length of the plate.

37. Drying.—The drying of the negatives is usually accomplished by placing them side by side in a *drying rack*. The latter should be so situated that the air has free access to the plates, as it is well that the latter dry as quickly as possible. This is particularly important in sultry weather, and a stream of air from an electric fan would then be of advantage. Do not put them in an open window where the sun can reach them, as the gelatin will quickly dissolve and run off.

The graduation in density of a Roentgen ray negative is often very limited; it is, therefore, well to call attention to one fact that may give cause for errors. If a negative is changed in position while drying, so that some parts have dried more quickly than others, then the latter will appear denser and show distinct marks. The plates should, therefore, be left undisturbed until the drying has been completed.

38. Storing of Negatives.—After a negative is dry, it may be marked with some number and a record kept of the date, exposure, and other useful data. The number must be written in a reversed position on one corner of the film. Some operators have a series of small numbers made of wire, which may be pinned on the front of the envelope and be skiagraphed with the other image.

We think that the simplest way to store negatives is to put them into the box in which they were originally, marking the outside of the box with the numbers contained therein. Negatives will not stand much handling, and will easily receive scratches that in this way of storing may be avoided.

Others prefer to have a case with a number of shelves, the depth of which may be about 16 inches. The distance between shelves should vary according to the length of the plates, the largest plates being on the lower shelf. In connection with this, there should be a catalogue giving the name of the patient, the number and size of the plate, and other necessary information.

INTENSIFICATION AND REDUCTION.

39. Intensifiers.—If a high-vacuum tube is working through deep tissues, the resulting photographic image is inclined to be weak and lacking in contrast. The rays from such tubes are more of a penetrating nature and less active photographically. Negatives of this class must be *intensified* either by means of a combination of chlorid of mercury and ammonium chlorid, or by using the *Agfa* intensifier, which is more easy in its application.

Some operators intensify every negative without exception, finding that only in pursuing this method is it possible to make negatives of good printing qualities. The following formula by *Carbutt* is used to a great extent:

Water	20 ounces.
Bichlorid of mercury	½ ounce.
Ammonium chlorid	½ ounce.

If it has been decided to submit the negative to intensification, time may be saved by doing so immediately after the negative comes out of the washing box and before it is set up to dry.

40. Process of Intensification.—Immerse the negative in the above solution, observing that the longer it remains in it, the greater will be the final density. The tray must be frequently rocked while the negative assumes a whitish appearance, the density increasing until, finally, the negative is quite white. On the removal of the plate from this solution, it is washed again for half an hour and is then submitted for half a minute to a bath of *ammonium chlorid* (½ ounce in 20 ounces of water). Wash again for 5 minutes after this operation and then immerse the plate in an ammonia solution, 1 dram of *aqua ammonia* to 8 ounces of water, until the white image is darkened through to the back of the plate. Then wash again for about 5 minutes and set up to dry.

Should this intensification have proceeded too far, so as to make the skiagraph more or less intransparent, then the density may be reduced by immersing the plate in a solution of hypo (1 : 100). When sufficient reduction has been obtained, the plate is at once washed thoroughly and set up to dry, as usual.

When using the *Agfa* intensifier, the negative is simply kept in the same until it is sufficiently dense, and is then washed. If high densities are desired the mercury solution may be preferable.

41. Reduction.—In cases where a skiagraph has been overdeveloped to such an extent, as to make it difficult to study in detail, it may be improved by reduction. The simplest method to pursue for this purpose is to use a solution of 100 grains of ammonia persulfate in 10 ounces of water. The skiagraph must be previously soaked for ½ hour in water, and then left in the bath until sufficiently reduced. To stop further reduction, the plate is rinsed at once under running water and washed for ½ hour.

PRINTING PROCESSES.

42. The Print or Positive.—Having obtained a *negative*, the next operation is the making of a *positive* that will give the correct tints of the dark and light parts. Some physicians prefer to examine the negative itself for the information they desire, in particular when it is a question of very faint shadows, such as derived from calculi, etc. This is because the positive always loses some of the finer details found in the negative.

A positive may be made on paper, celluloid, or glass. The first is most in use, and is then simply called a **print.** It is paper coated with an emulsion of gelatin, albumen, or collodion, in which chlorid of silver is incorporated. The printing paper may be glossy or matt, the former giving more detail.

43. Printing Frame.—The apparatus required for making a positive, or print, is a printing frame, a rear view of which

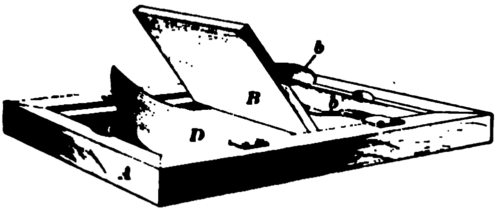

FIG. 2.

is given in Fig. 2. *A* is a frame with a shoulder on its inner side on which the negative *C* is laid with its film side turned upwards. On top of this is placed a sheet *D* of printing paper, corresponding in size to that of the negative, or, if only a small part of the latter is to be copied, then a piece just large enough to cover that part. The paper to be selected for this purpose may be any of the so-called *P. O. P.* papers, an abbreviation of *printing-out papers*, meaning, thereby, one that is covered with silver chlorid and gives an image visible without development. The paper is laid with its face toward the negative. On top of the latter comes the back *B*, which holds the paper closely pressed toward the negative, and which has for this purpose spring clamps *b*.

Turning over the frame it appears as in Fig. 3, the glass side of the negative *C* now being turned toward the observer. The frame is then placed so that the rays of the sun can strike the glass [illegible] in order to avoid the maximum [illegible] If the negative is "thin," that is, if the film is of small density, then it is preferable to print in the shade; this will tend to bring more contrasts in the copy.

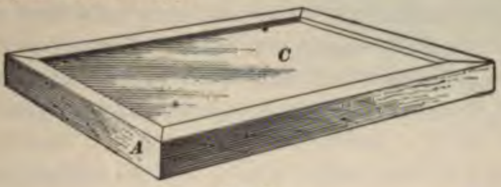

FIG. 3.

44. The Printing.—The time required for the printing will vary with the density of the negative, the time of day, and, also, whether it is summer or winter. It may be 5 to 6 minutes or as much as 20 to 30 minutes. In order to examine the progress of the printing, the back *B*, Fig. 2, is divided into two parts, hinged together so that one-half may be opened and the print turned back and examined without danger of changing its position relative to the negative. This examination should take place in subdued light, and the face of the print should not be touched by the fingers. Likewise, one should be careful to so open and close the spring clamp that the back itself is not moved, and with it the paper. The printing should proceed until the paper has received a tone somewhat darker than that desired for the finished print, as it will lose some of this tone in the succeeding operations. How much deeper to print will depend on the paper selected.

45. Fixing.—The print is now fixed similar to the plate. The formula required for this purpose is always given in the package containing the paper.

46. Toning.—As the print emerges from the fixing bath, with a tone or color that is not generally liked, it is customary to give it a gold tone before fixing by submitting it to a gold toning bath in which it receives a rich, dark-purple color. It is then washed, fixed, and again washed for 1 hour in running water.

47. Combined Toning and Fixing.—To many persons this preliminary toning and washing process is somewhat troublesome, and attempts have been made again and again to combine toning and fixing in one operation, with varying success. This is caused by the fact that the bath may retain its toning ability while its fixing salts may have been exhausted. Prints not properly fixed will fade. The writer has found the following combined toning and fixing bath, recommended by Nicoll, to answer all requirements and to give a variety of colors:

Hypo	2 ounces.
Solution of gold chlorid (1 to 60)	2 drams.
Water	16 ounces.

First dissolve the hypo, then add the gold solution and let it stand 24 hours before it is used. This bath works better when it gets a little older.

The solution is poured into a toning tray and the prints put in, one by one, without preliminary washing. They must be kept in constant rotation to insure even toning and fixing. Usually, this is done by constantly taking the lowest print and placing it on top; see that they are well covered. Places on the prints touched with the fingers will not tone. When the various prints have received the desired tone, they are placed in a tray filled with water, and after all have reached this stage they are given three or four changes of water and are then put through the final washing process, as before.

To insure the safe action of the above toning bath it must, from time to time, be strengthened by throwing one-half of it away and adding 8 ounces of fresh solution in its place. It is supposed that 1 grain of gold tones about fifteen 5 × 7 prints. For each fifteen prints, or their equivalent (about 500 square inches), this renewal of the solution should be made, and in this manner it may be used for years.

48. Self-Toning Papers.—There are also to be had what are called "self-toning" papers, that do not require to go through a toning process, as they tone simultaneously with their fixing.

49. Developing Papers.—Recently, *bromid papers*, such as those made by Eastman, the Nepera Company, and the

Rotograph Company, and many others, have been used for Roentgen ray prints. These are furnished either with a glossy or mat surface. The latter kind will, unless the negative is a very strong one, not give as much detail as the glossy variety. Papers of this class have the advantage that they may be printed at any time in the dark room by means of a gaslight or lamp. It only requires a few seconds to do this and they may be printed in quantities, absolutely uniform. Their treatment is similar to that of the plate, requiring no toning.

50. Blue-Print Papers.—When it is desirable to make preliminary copies of a skiagraph without much expense or trouble, then the so-called *blue-print paper* is of some convenience. Belonging to the mat surface class, it may not always show much detail, though some grades leave little to be desired, even in that direction. There are various kinds in the market, but one of the best for this purpose is the "French Satin Jr." These papers are exposed in the printing frame to the sunlight until the deeper shadows assume a gray-green color similar to that of bronze. The after manipulations consist simply of washing the prints in various changes of water until the iron salts unaffected by the light are removed from the paper, and no further coloring of the water takes place. These prints are permanent.

51. Appearance of Print.—A print from a skiagraph will show the dense parts of the object in dark tones. This is because the light through these parts will affect the sensitive plate in a lesser degree than those from the more transparent parts; consequently, the skiagraph will be thinner or less dense where it represents dense objects. When a print is made, these thin parts will then allow more light to reach the paper and there a deeper blackening will be produced.

MOUNTING.

52. The **mounting** of a print consists in pasting the latter upon a suitable, stiff support, partly to facilitate its handling and partly to prevent its being bent and cracked. As so many good pastes are found in the market, such as Higgins' and

Carter's photo pastes, it would pay better to buy one of these than attempt to make one. Most of these pastes are rather stiff, and it may be of advantage to add about 1 teaspoonful of water and mix well. The paste is applied with a stiff, flat bristle brush, about 1¼ inch wide, to the back of the previously moistened print, being sure to brush clear up to the edges. The print may then be taken up and laid on the mount, taking care not to handle it near the edges, but rather near the middle, otherwise the print will lose some of its paste and will not stick along the edges. After some experience it may be possible to reverse the process and lay the mount on the print, then quickly turn both around and readjust the print if necessary. After the print is in position, a sheet of paraffin paper, or some other smooth paper, is laid over it and a rubber roller, a so-called roller squeegee, is rolled over it with a pretty good pressure. The prints should dry with a free access to the air.

Some prints demand trimming before being mounted. For this purpose a **print trimmer** is very handy. This consists of a long knife mounted on a graduated square board.

DIFFERENCE BETWEEN A SKIAGRAPH AND AN ORDINARY NEGATIVE.

53. Ordinary Photographs.—It is necessary, here, to call attention to an important difference between a skiagraph

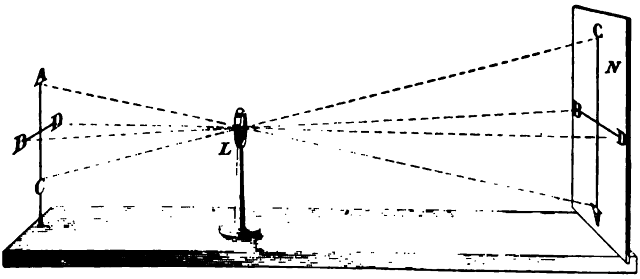

FIG. 4.

and an ordinary negative, which, if not kept in mind, may be the cause of serious errors in a diagnosis, or in locating foreign substances in the body. This difference is caused by the fact that in a skiagraph, it is a question of transmitted, and in a photograph, of reflected, light.

In Fig. 4, the process of taking a *photograph* is shown in principle. On the left is a cross provided with the four letters *A*, *B*, *C*, *D*. Reflected light rays pass from these through the lens *L* to the sensitive plate *N*. The rays, crossing one another in the lens, will produce an image on *N* that is not only inverted but is also reversed, as can be ascertained by turning the figure upside down. The film, or sensitive side is, in this instance, as with skiagraphs in general, turned toward the object. On turning over the negative and observing it from its front or glassy side, it will appear as in Fig. 5. This is the position it occupies in the printing frame, and the print will, therefore, also have this same arrangement of parts.

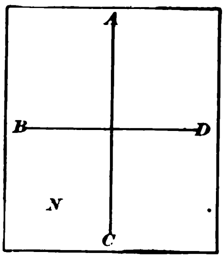

FIG. 5.

54. Skiagraphs.—When a *skiagraph* is made, the situation is different. In Fig. 6 we have at *T* a Roentgen ray tube projecting its rays through the same metal cross and throwing a direct shadow on the sensitive plate *S*. In this case, as before, the film side is facing the observer. Now, on placing the negative in the printing frame with its film side toward the printing paper, the plate and print will both appear as shown in Fig. 7, that is, reversed. *Left* is now made *right*, and vice versa.

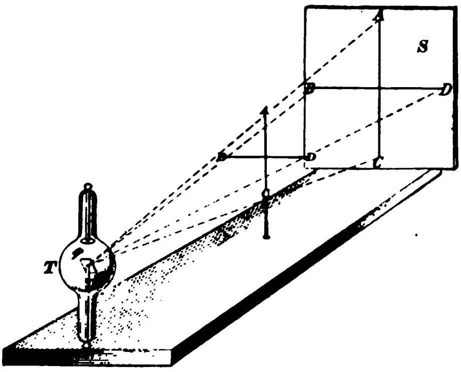

FIG. 6.

As a consequence of this, we can suppose the case, that a physician takes a skiagraph, sends it to the photographer to have it developed and copied, and receives in return a print showing the above characteristics. Not being familiar with the printing method, he may suppose it is a correct copy of his negative and may act accordingly. While this may make no difference in a good many cases, in others it may.

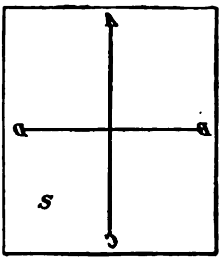

FIG. 7.

55. Prevention of Reversal.—A method of preventing this reversal would be to expose the sensitive plate with its sensitive side turned *away* from the tube. Objections to this would be that the rays would first have to pass through the glass and thereby lose some of their strength. Another way would be to insert the negative in the printing frame with the film side turned outwardly. It would not do to print this picture in the shade, as the outlines would be diffused. Neither would it do to print it in the sun, unless the frame, after the several examinations, each time was returned to its original position. Printing by artificial light on one of the developing papers might do, as in that case the frame does not change positions during the printing and the light also remains stationary.

As a safeguard, the following rule may be formulated: *An ordinary negative, to show a correct image, should be observed from its glassy side, a skiagraph from the film side.*

Some physicians prefer to have the bony structures shown in white on a dark background and make, for this purpose, first a glass positive by exposing a sensitive plate behind the skiagraph and then develop and fix it as an ordinary plate. This positive will now show the image similar to a print and by using it in the printing frame in place of the negative, the bones will show white on darkly tinted tissues.

If this glass positive is made while its film side is turned toward the negative, it will, in the prints, give a *correct* position of the parts skiagraphed.

56. Perspective of Skiagraphs.—For reasons given in Arts. 1 and 57, it is not strictly correct to speak of perspective when considering a skiagraph. In some skiagraphs there is a quasi-similarity to a perspective picture, but when considering the subject, one will find that the laws on which this perspective is based, are entirely contrary to those of ordinary perspective.

When studying the picture of a landscape, the objects in the foreground are found to be full of details and with sharp outlines. As the eye recedes to parts farther away, details will be lacking and a general haziness and softness of outlines will prevail. Simultaneously the objects will decrease in apparent size.

Observing a skiagraph from its glassy side, we may see something similar. There may be some objects apparently situated in the foreground, full of details and sharply outlined. Back of these and partly hid by the former some other parts are found, more diffused and more soft in outlines. We may, in fact, seem to see objects situated in various planes, one behind the other, with a gradual increase in diffusion. Apparently this ought to be a good perspective, but let us see how these effects are produced.

It is clear that when a skiagraph is taken of an object composed of parts situated at unequal distances from the plate, that those parts which are immediately adjoining the sensitive plate will have sharp outlines and numerous details. The other parts will show a degree of diffusion according to their distance from the plate.

But this is not all. From the diverging nature of the rays those parts more distant from the plate will produce shadows with greatly increased dimensions. If, now, the observer occupies the same position relative to the skiagraph as the tube, he will see those parts that adjoined the plate, and that therefore are the most distant, with the clearest details. Those nearer to him will, to be sure, show an increase in size, but will also grow more diffused. Looking at the plate from its glassy side will not improve matters. Not considering the reversal of the image, we find that objects *increase* in size as they recede from the foreground.

If this skiagraph is studied from its film side by a person ignorant of these peculiarities, but familiar with the laws of ordinary perspective, he will instinctively receive the impression that those parts with the clearest details are next to the observer, and that the others are the farther away the more they are lacking in detail. Acting in opposition to this deduction is the other one, that the parts more clearly outlined are partly overlapped by parts of more diffuse outlines and that, therefore, the latter somehow must be nearer.

We see, then, that the perspective of a skiagraph is constructed on rather contradictory principles. It is, therefore, not always easy to readjust the received impressions and to get a clear conception both as to size and location of the parts composing a skiagraph, and it will take some experience before this difficulty is entirely overcome.

As distortion in a skiagraph cannot be entirely prevented, some universal standard should be agreed on regarding the position and distance of the tube relative to the objects skiagraphed. It will then be possible to know *where* to look for distortions and *why* they are produced. For this purpose, Doctor Williams, surgeon to the City Orthopedic Hospital, London, makes the following suggestions:

1. That there should be certain points on the human subject over which the anode should be placed, and that on the skiagraph a small (A) mark should denote the position of the anode.

2. That the distance from the tube to the plate or film never be less than 18 inches.

3. That in the lower extremities they should be placed at a right angle with a line drawn between the two anterior superior spines, and that the spine be absolutely at right angles to this also. In the case of one hip-joint being fixed in, say, adduction, then the sound limb should be placed at a right angle.

4. In the upper limbs for the shoulder-joint the arm should make with the mid-line an angle of 45°, and the hand rest with the palmar surface downwards. The opposite sound parts should always be shown for comparison, taken, of course, under exactly the same conditions. In the elbow-joint the

internal condyle being on the film, the anode should be placed over a point about 1 inch below the external condyle in the line of the forearm. This is for the purpose of opening up the joint as much as possible.

5. For the trunk, it should be placed as symmetrical as possible, and in the case of the neck vertibræ the best position is found to be with the occiput well over the end of the plate, and the chin high up, but exactly in a straight line with the sternal notch.

57. **How to Study a Skiagraph.**—In many skiagraphs the gradations of the shadows are so delicate that they cannot be discerned under ordinary circumstances. Some arrangements should therefore be made to facilitate the study of them under the most advantageous conditions. Various appliances have been suggested for this purpose. First in order is the background, against which the skiagraphs are viewed. It should be such as to exclude all foreign objects from view and be of an even, fine-grained texture. A pane of ground glass will fulfil these requirements. If a lower window sash is provided with such glass, and the skiagraph viewed against this background, while a curtain covers the upper sash, much will be seen which otherwise would escape attention. While this arrangement may do under ordinary circumstances, it is not good enough for finer work. In such cases *all* light, except that passing through the skiagraph, should be excluded. For this purpose an appliance similar to that used by photographers, when retouching negatives, may be made. It consists mainly of a slanting desk surrounded by a hood that keeps out the side and front light. In the center of the desk is a square aperture covered with ground glass; some distance below the latter, and in a horizontal position, is a mirror, which serves as a reflector. By means of this reflector the light, coming through a window, is thrown upwardly through the ground glass and the skiagraph that is laid on the latter. The ground glass should be large enough to include the largest size of skiagraphs. When smaller sizes are studied, then a sheet of cardboard with an opening corresponding to that of the skiagraph, may be laid over

the ground glass. All extraneous light may thus be kept away also from the smaller skiagraphs. The room should preferably be darkened, leaving an opening in front of the lower window just large enough for illuminating the reflector. When daylight is not available, artificial light may be reflected into the ground glass, or, if preferable, used altogether.

In this case a box may be made with a slanting front consisting partly of a pane of ground glass. Inside of this front may be a number of incandescent lamps that throw their light toward a mirror, from which it is reflected toward the ground glass. The lamps should be prevented, by means of suitable shields, from throwing their light directly on the ground glass. Arrangement should be made for regulating the intensity of the light in accordance with the density of the skiagraph. It has been found that by observing skiagraphs illuminated in this manner, from a distance of 10 to 30 feet by means of an opera glass, they would show a remarkable increase in details and contrasts. They seem also to gain in perspective depth.

STEREOSKIAGRAPHY.

58. Principles.—The objection is sometimes made to skiagraphs that they lack depth or perspective, and are mere map-like representations of organic structures. In a measure this is true, and cannot be otherwise, but at the same time this is not in general found very objectionable, as in most cases it is more a question of locating and outlining parts than of a pictorial representation of same. At the same time, there are cases where it is of advantage to see the relative position and depth of overlapping parts. For this purpose stereoscopic skiagraphs serve admirably.

It is presumed that the principle on which ordinary stereoscopic views are made is well known, and it will, therefore, suffice to say that the whole procedure consists in taking two skiagraphs of the same object from two different points of view. These two views are then combined by means of a Wheatstone reflecting or a Brewster refracting stereoscope into one, which gives the relative depth and location of the different parts.

59. Apparatus.—The instrument described in Art. **114**, *The Physics of Roentgen Rays*, will serve very well for this purpose and may be used in the following manner: The object is laid with its long axis parallel to the bar *A* and with its central part vertically under the anode when the tube occupies its central or zero position. The height of the tube above the object should be about 12 inches, as this corresponds with the average distance between the eyes and a picture, when viewing the latter. The distance between the eyes themselves being on an average 2½ inches, the tube is moved to the left one-half of this distance, or 1¼ inches. After inserting a sensitive plate with its middle point vertically under the central part of the bar *A*, an exposure is made. The tube is now moved 1¼ inches to the right of the zero point and another plate slid under the first, to insure an identical position, when the plate already exposed is removed. After exposing the second plate, two skiagraphs are produced, taken at two points 2½ inches apart.

When studying these views in the stereoscope, either as skiagraphs or as paper positives, it should be kept in mind what was said in Art. **54** regarding the reversal of the image. This is of particular importance when it comes to locating foreign bodies by means of stereoskiagraphs.

Practical Applications of Roentgen Rays.

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REGIONAL DIAGNOSIS.

HEAD AND FACE.

1. Position of Patient.—The head can be fluoroscoped while the patient is seated on a chair. It may be skiagraphed in the same position, but it is better to have the patient on a table or floor. The facial portion of the skull can be clearly outlined, but the larger portion of the cranium is darkened by the shadow of the brain, as well as by the shadow of the opposite cranial wall. To study the relations properly, a sagittal and a frontal exposure must be made. If the left side of the head rests on the plate, the irradiation taking place from the right, the soft tissues, and the galea aponeurotica are recognized as a light shade. The soft tissues of the nose, lips, and of the chin are very conspicuous.

2. Visible Portions.—Of the bony parts, the external occipital protuberance, also the orbital, nasal, and sphenoid cavities are easily recognized. In the center of the temporal bone, the light shade of the external auditory canal is seen. Below the latter, the small cavities of the mastoid process may be perceived; the zygoma is also quite distinct. The nasal bones

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and the superior maxilla, showing the quadrangular shade of the antrum Highmori, especially can be well represented.

The nasal process, the hard palate, the alveolar process and its cells and teeth, and the inferior maxilla—showing its mental foramen, the protuberance, the external oblique line, the angle with its two processes, can be well demonstrated. With these osseous structures, the shades of the tongue and the velum palati contrast well. The motions of the velum palati and of the tongue can be easily studied. Schneier has considerably increased our knowledge on the physiology of the phonation by his fluoroscopic studies in this connection.

By placing the patient's face on the plate and the tube behind it, the margins of the orbit, the frontal and nasal cavities, and the nasal bones appear well outlined.

INFANTS.

3. In infants, the details can be much better represented. Even the interior of the ear (cochlea and semicircular canals) can be shown. Plate I, for instance, shows the internal structures of the skull, among them the sella turcica. It represents a boy, age 5 weeks, who shows a spherical, non-pulsating tumor, of the size of an orange, projecting from the nasofrontal region, and sinking downwards to the alae nasi. At birth the tumor was a trifle smaller. The walls of the tumor were thin, and the integument appeared normal. Contractions of the tumor were observed, especially while the child was crying. During sleep the tumor appeared somewhat smaller. There was exquisite fluctuation, and the contents could be pressed almost entirely within the skull, which did not cause any reaction. Pulsation of the brain could not be detected, nor could the border of the cranial opening be felt distinctly. In view of these facts, especially of the inability to palpate a solid mass with certainty, a meningocele was suggested.

The Roentgen rays, however, modified the diagnosis. A skiagraph showed behind the light shade, representing the fluid, a dark one, which had to be interpreted as a solid mass, confined to the area of the large, triangular bony opening. That this was cerebral substance was verified by the subsequent

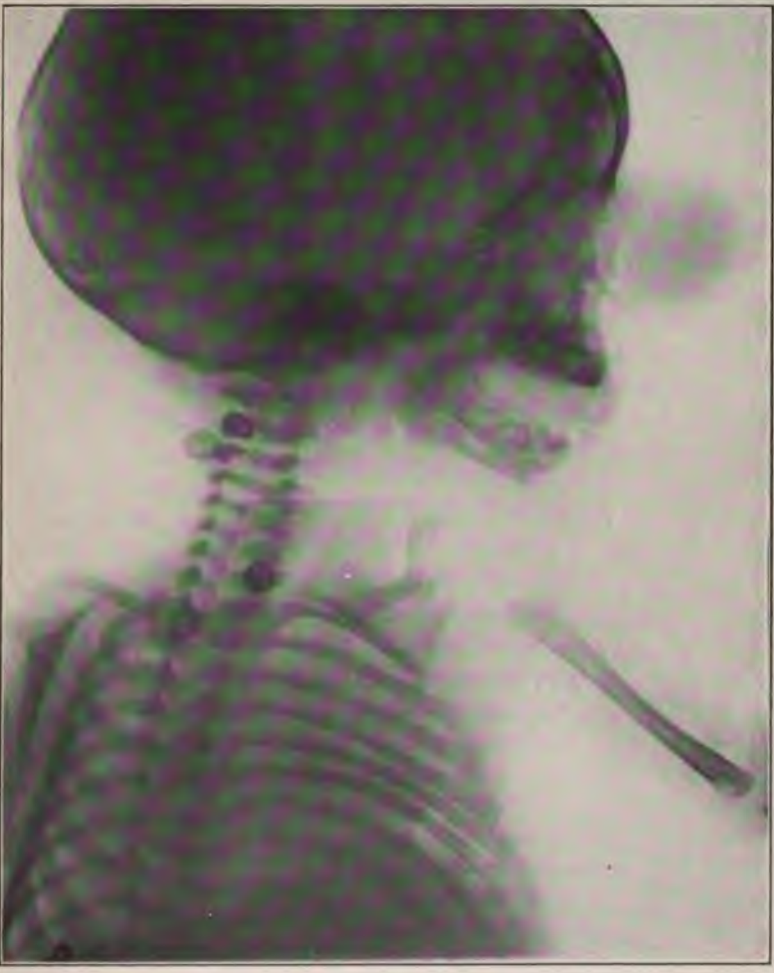

PLATE I.

***Hydrencephalocele**, Showing Bony Canal as Well as Fluid and Solid Areas of the Tumor, Besides the Hiatus Between Nasal and Frontal Bone.*

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operation. The skiagraph showed that the nasal bone was shifted downwards so that the interspace of the width of a man's thumb was left between it and the frontal bone. After a constriction of the base of the tumor had been made, for the purpose of ascertaining whether cutting off the circulation and pressing upon the contents would produce any reaction, a prophylactic silk suture was conducted around the whole circumference of the tumor at its base, in order to be able to control any excessive hemorrhage by quickly pulling together the suture ends. An elliptic flap was then dissected from the center of the tumor and the cavity opened laterally. After about one tablespoonful of normal cerebrospinal fluid had escaped, further exposure of the sac revealed its lining, consisting of dura mater, partially protecting degenerated cerebral substance. Near the base, according to the darker shadow of the skiagraph, cerebral substance, covered by dark-red, velvety, succulent, and easily bleeding tissue, protruded. After severing the protruding portion from its lateral connections, which were thinly spread over the walls, it was possible to reduce it into the cranial cavity. Two-thirds of the sac were now removed and the remaining stump was freed from the frontal bone, including the periosteum, until apposition without tension could be obtained. The edges were then united with thin formalin catgut, and supported by another row consisting of overlapping soft tissues; finally, the skin edges were united with a stout iodoform silk. Although the loss of blood was scant, the infant appeared very anemic after the operation, and refused nursing until 2 hours afterward. No stimulants were administered. There was no reaction, and at present, 1 year after the operation, the child appears normal in every respect. Another skiagraph, taken at this time, shows that the bony canal became considerably smaller.

FOREIGN BODIES IN THE EYEBALL.

4. To locate foreign bodies in the eyeball, the exposure is best made in the oblique direction (Dahlfeld and Pohrt succeeded even in skiagraphing birdshots of the size of 1 to .4 mm.), so that the foreign body appears either in front of, or behind, the orbital margin. The localization of foreign bodies in the skull is sometimes connected with considerable difficulties. If foreign bodies are situated in the bones, two skiagraphs, at least, are required—one to be taken anteriorly, or posteriorly, and the other laterally. By simply crossing their diameters diagonally, the distance from the outer surface can be determined. The same principles of localization, more or less modified, apply to the intracranial localization of foreign bodies.

5. Method of Extracting Foreign Bodies.—In extracting foreign bodies, it has been found quite helpful to measure the distance of the foreign body from the nearest bone prominence in both skiagraphs; also, to compare the skiagraph with the features of a normal skull. In the case illustrated by Plates II and III, a bullet had entered the right temporal region, and, by passing the orbit transversely, caused traumatic enophthalmos (injury of the sympathetic roots of the ciliary ganglion). The optic nerve was pierced, and considerable hemorrhage of the choroid and retina had taken place. Neither the comminution of the orbit nor any injury within the extent of the left antrum Highmori, through which the bullet had taken its course, could be demonstrated by the rays, but the bullet itself was located in the left pterygoid process. The distances were first measured, during the operation, simply with a graded probe; the distance between the nasal bone and the bullet being taken at the first skiagraph, which determined the direction and the extent of the skin incision, and then the same distance being taken from the side skiagraph, which determined the depth of the incision. Although the bullet was imbedded in the bone and was surrounded by new bone-tissue, it was not difficult to detect and extract it after the antrum Highmori had been exposed by osteoplastic resection of its anterior wall. Without the aid of the rays it would have been impossible to trace the bullet. In fact, it was remarkable that it had taken so long and destructive a course without causing any other symptoms than a dull continuous pain all over the skull. The bullet was so compressed that it had changed its longitudinal form into a flat disk, which explains the shape of the bullet in the skiagraph.

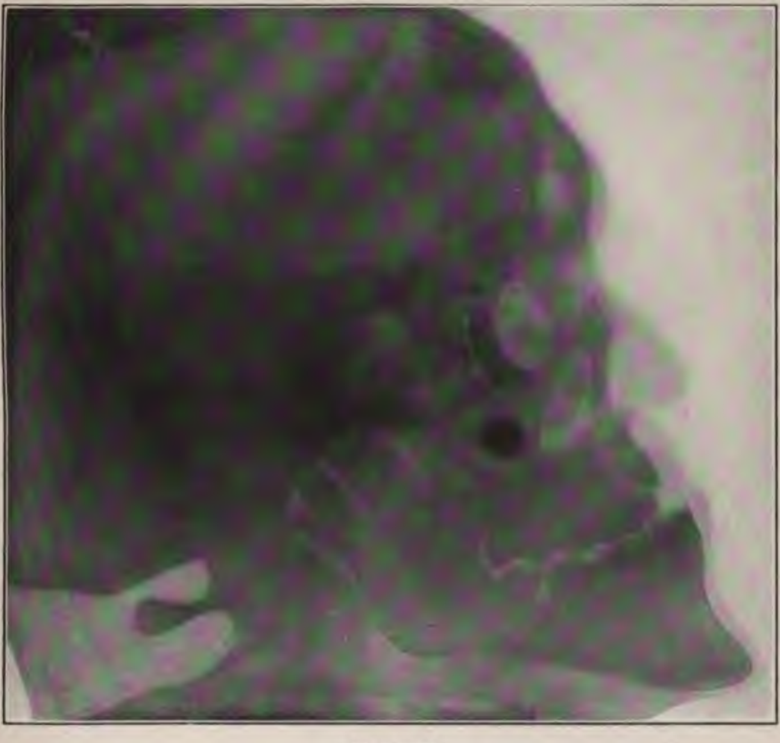

PLATE II.

Bullet Located in Left Pterygoid Process. (Lateral Position.)

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6. Marking Skiagraphs for Reference.—For localization of foreign bodies in the eyeball, it is advisable to place miniature letters at the inner and outer end of the eyelid and one at the orbital margin. Special attention is called to the representation of the defect in the superior maxilla, Plate III, which indicates that the patient is suffering from a cleft palate.

FRACTURES.

7. Fractures of the Cranial Bones.—In fractures of the facial bones skiagraphy is of great value. In one instance it was possible by skiagraphy to illustrate the depression of the outer and the protrusion of the inner table in the case of a man, age 25 years, who had sustained a transverse fracture of the frontal bone when a child. As the patient suffered from epileptiform attacks after the injury, which was originally taken for a superficial lesion only, osteoplastic resection was performed 15 years later. The position found at the operation verified the correctness of the skiagraph. The attacks have since stopped (the time of observation being 2 years after the operation).

8. Fractures of the Facial Bones.—Fractures of the nasal bones, the alveolar process, and the zygoma, can be represented by the rays. Skiagraphy of the base of the skull can be relied on only under very favorable circumstances. Fracture of the inferior maxilla may also be skiagraphed. After the fragments are wired it is of value to keep them under control by repeated skiagraphic examinations.

ROENTGEN RAYS IN RHINOLOGY.

9. The Roentgen rays have furnished valuable contributions to our knowledge of rhinology. The frequent presence of foreign bodies in the nose gives many opportunities for their use. The examination of the frontal sinus is of still greater importance. The absence of nasal bones and of the hard palate can be well studied (see Plates I, II, and III). In suppuration of the antrum Highmori the skiagraph determines the affected side, which shows a much darker shade than the normal.

ROENTGEN RAYS IN DENTISTRY.

10. The relation of the dental roots and their position, the presence or absence of the milk-teeth, as well as of the permanent teeth in children, or of an old root, or foreign bodies (fillings, pieces of chisel broken off, for instance, while excavating a carious tooth), and the extent of an alveolar abscess can be clearly demonstrated.

Sometimes it is of great forensic importance to determine the age of an infantile corpse by skiagraphing the teeth. As a rule, it will suffice to place the face portion nearest the tooth in question on an ordinary Roentgen plate. If fine details are demanded, flexible films may be introduced into the oral cavity, where they will adapt themselves to the contours of the maxilla.

In a case of severe neuralgia, the question arose whether an old root was the cause of the evil. The skiagraph showed that the small screw of the adjacent artificial tooth had been attached in a wrong direction. After it was unscrewed the pain ceased.

NECK.

11. Position of Patient.—The neck may be fluoroscoped as well as skiagraphed while the patient is seated on a chair, but for skiagraphy it is better to have the patient reclining on a table or the floor, a small pillow supporting the head. The best exposures are made by turning the patient sidewise. In this position the cervical vertebræ are better shown, the angle of the inferior maxilla not overshadowing their upper portion. The dark shade of the hyoid bone, as well as the lighter shadow of the larynx, the epiglottis and the trachea are well represented. The esophagus, while not conspicuous, can be made out behind the trachea as a hollow space. The bodies, the spinous, and transverse processes, as well as the intervertebral foramina, appear very conspicuous.

12. An Ideal Method.—Aneurism of the carotid and the subclavian arteries are demonstrable. Tumors of the larynx, especially chondroma, and ossification are easily recognized.

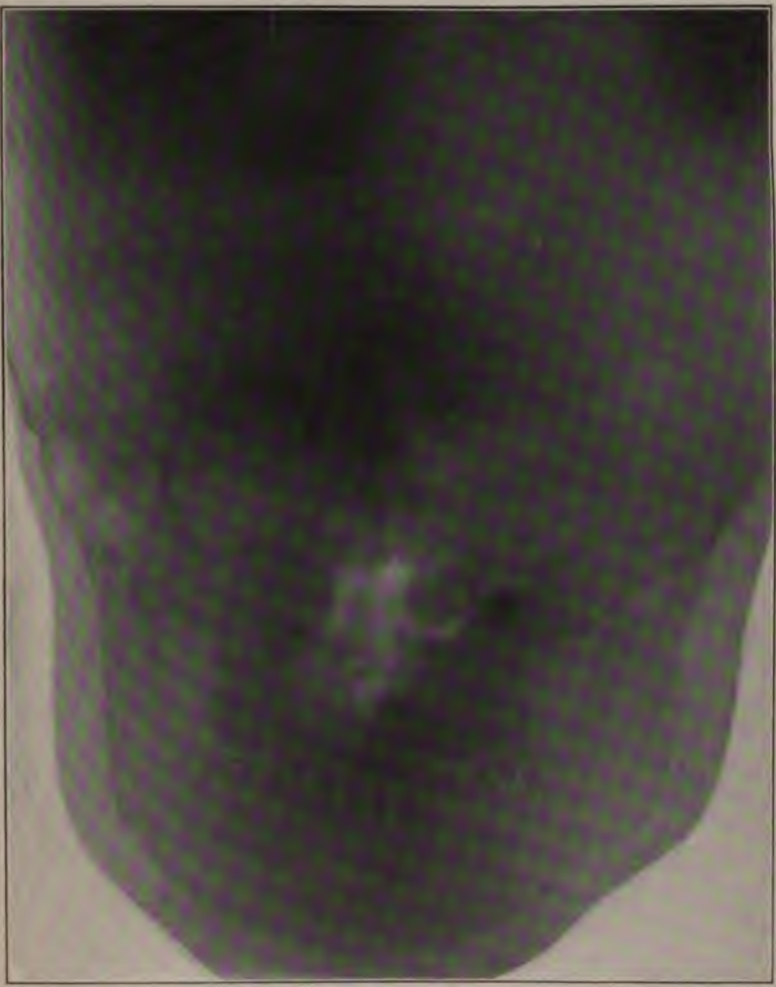

PLATE III.

Bullet Located in Left Pterygoid Process. Attention is Called to the Cleft Palate.
(Frontal Position.)

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Exploratory incision for suspected foreign bodies in the pharynx, tonsils, larynx, trachea, and esophagus have become unnecessary. The rays, as explorers, have indeed realized the old ideal desideratum: *Cito, tuto, et jucunde.* Whoever has felt the uncertainty in diagnosticating foreign bodies in these regions, and especially who has been tempted to resort to adventurous procedure, must keenly feel the blessings that the rays have brought. If the Roentgen rays would have done nothing else but located foreign bodies in the throat, they would represent one of the greatest blessings to suffering humanity.

13. Removal of Coin From Throat.—As an illustration of the removal of a coin, the following case may be mentioned. A baby of 1 year had swallowed a penny 9 days before. When examined at a hospital it was decided that the foreign body had passed the esophagus. The mother watched the feces of the patient carefully, but did not find the penny. In the meanwhile, the baby became feverish and vomited frequently. When the child was first seen it gave the impression that a grave disease was present. Instead of introducing an esophageal probe, as was done in former years in such cases, the fluoroscope was used, which located the penny at once on a level with the second rib. A coin catcher was then introduced. After having passed the isthmus a resistance was felt; the instrument was then pushed forwards, turned, and withdrawn, until considerable resistance was encountered, when the steel attachment of the coin catcher broke, so that coin and catcher were both in the esophagus. After many unsuccessful efforts, the broken fragment of the coin catcher was extracted (with an esophageal forceps). The coin was now propelled into the stomach with a whalebone pusher. No sooner was this accomplished than the child vomited and the penny was ejected.

14. Removing a Needle.—Another remarkable case is that of a girl, age 15 years, who, on the evening previous to the examination, had held a needle between her teeth, which, when frightened by a sudden noise, she swallowed. Medical care was summoned at once. The distinct pain, located at the region of the first and second dorsal vertebræ, was attributed to the injury, which had presumably been caused by the needle passing the esophagus. The pain becoming more intense during the night, the patient was brought to the hospital where, after being under anesthesia, she was advised that the needle was in the stomach and would soon pass per vias naturales.

Later, when the neck was examined with the fluoroscope, the needle was discovered at a level with the first rib. By introducing the finger into the esophagus, the needle could be distinctly felt at this region and was successfully dislodged so that it was possible to extract it with an esophageal forceps. Without the fluoroscope, it would not have been possible to proceed with such absolute certainty.

If the fluoroscopic examination had not been successful, the thorax and abdomen should have been skiagraphed and the foreign body would probably have been located somewhere in the esophagus or the stomach.

15. Gocht reported the case of a patient who had been submitted to repeated operative procedures on account of severe pain in one of his tonsils, without obtaining any relief. The Roentgen rays revealed a needle fragment deeply imbedded in the tonsillar tissue, where it was inaccessible to palpation, of course.

16. Fractures of Hyoid Bone, Larynx, and Vertebræ.—Fractures of the hyoid bone, the larynx, and the vertebræ can be easily recognized. Plate IV illustrates the case of a woman, age 21 years, who, in falling downstairs during an epileptic fit, sustained a fracture of the right transverse processes of the first, second, and third cervical vertebræ. There was a fracture within the cervical vertebræ, at once recognized by the family physician, but its localization, and especially the fact that only the transverse process was concerned, could be verified only by means of the Roentgen rays.

Reduction was accomplished under the guidance of the Roentgen rays. One of the vertebral fragments was felt as a protruding mass from the posterior pharyngeal wall and was pushed backwards. The after-treatment consisted in the application of Glisson's cradle. Recovery was perfect after 9 weeks.

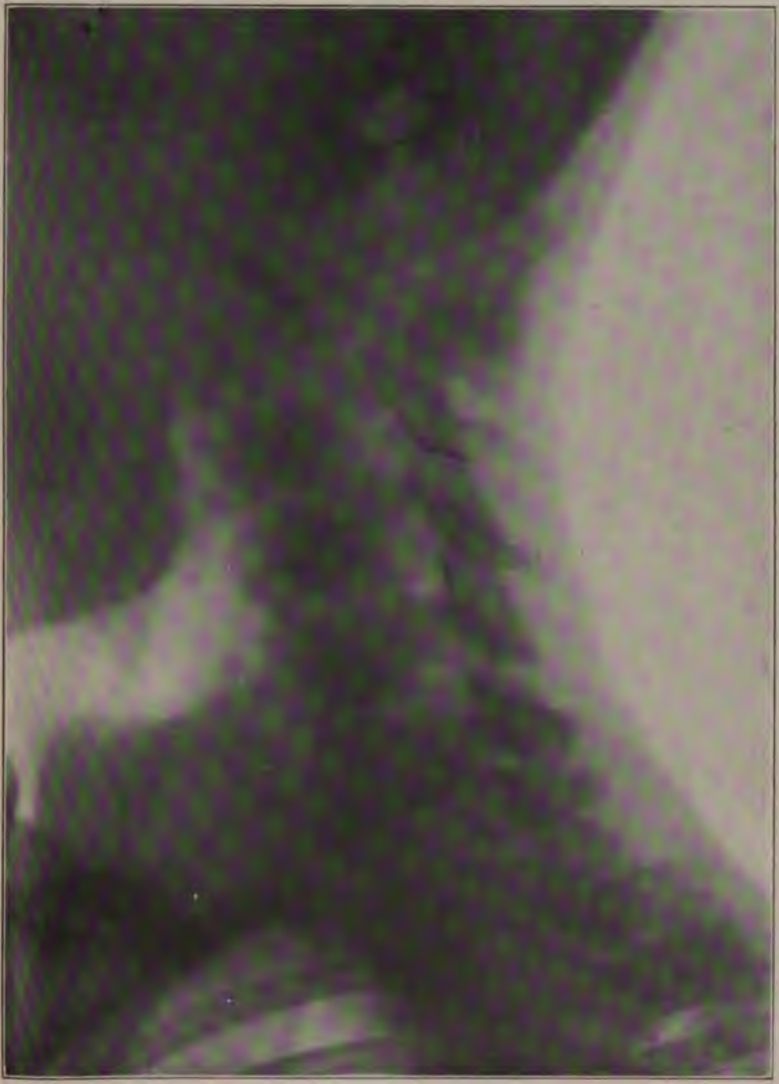

PLATE IV.

Fracture of the Right Transverse Processes of the First, Second, and Third Cervical Vertebra.

17. Goiter.—The various types of goiter may also be studied. Wherever calcification is found, strumectomy should be advised, provided the disturbances are of a severe character. Otherwise internal treatment combined with the local injection of iodoform-ether is to be tried.

CHEST.

18. The chest may be fluoroscoped while the patient is standing, or seated on a chair. Skiagraphy is best done on a table or the carpeted floor. The dorsal vertebræ, the ribs, the clavicle, and their injuries and diseases, especially those of the heart, the lungs, pleura, and the diaphragm, can be easily seen. Foreign bodies in the thoracic cavity are easily represented, and most diseases of the thoracic cavity can be studied by the aid of Roentgen rays. An enlargement or displacement of the heart and effusion in the pericardium can be represented, as well as aneurism and the various kinds of mediastinal tumors.

Pneumonic solidification, phthisical foci, cavities, abscesses, tumors, bronchiectasis, emphysema, and retractions of the lungs can be recognized by fluoroscopy as well as by skiagraphy. Effusions in the pleural cavity, also fibrous swards of the pleura, are noted. Irregularities of the excursions of the diaphragm can be well studied. Nowhere does the usefulness of the fluoroscope become so apparent as it does in chestwork, because the intrathoracic organs can be observed while in motion.

19. Skiagraphing the Thorax.—In skiagraphing the patient in the dorsal position, anterior irradiation, the spinal column, as well as the posterior portions of the ribs with their heads, necks, and tubercules become apparent, especially at their right side. The direction of the posterior ribs is downward, while that of the anterior is upward. The image of the anterior aspect of the ribs is naturally diffused on account of the much greater distance from the plate.

20. Skiagraphing Anteriorly.—In skiagraphing anteriorly, posterior irradiation, the patient lying on his abdomen, the clavicle, the sternum, and the adjoining ribs are well defined. The spinal column and the posterior ribs appear diffused. The heart being situated so near the anterior chest wall, shows its outline well marked. The shade of the large blood-vessels is less distinct. The shadows of the normal lungs, especially the middle portions, are very light. The left middle portion of the lungs must be studied from the side, because, if examined from the front, it becomes obscured by the large triangular shade of the heart (Plate XXVI).

21. Fractures of Dorsal Vertebræ.—A clear skiagraph of fracture of the dorsal vertebræ represents the type of the fracture, the size and number of the splinters and their location so well that the indications for the mode of treatment are clearly set forth. If there is only slight angular displacement, reduction can nearly always be accomplished. But in the event of intraspinal hemorrhage and when bone fragments, driven into the canal, press upon the cord, operative interference is required.

Under the application of Roentgen rays, the operations, which formerly had been confined to exploration, have become much more encouraging. The field of operation being outlined by the skiagraph, the *modus operandi* can be determined before operation. While at one time it was deemed advisable to expose a large portion of the spinal column in order to ascertain that every possible injury had really been reached, now all the operative procedures can be carried out under the indication of the rays with ease and security, even the length of the incision necessary for the removal of bone splinters being shown by the skiagraph.

It is surprising that surgeons, who find it most natural to relieve, by immediate operation, brain pressure caused by a depressed fracture of the skull, should hesitate to perform the similar operations upon the spinal column. Nothing, indeed, is more natural than reduction or removal of a fragment pressing on the spinal cord.

22. The treatment of *scoliosis*, *kyphosis*, and *lordosis*, can be well controlled by repeated skiagraphic observations.

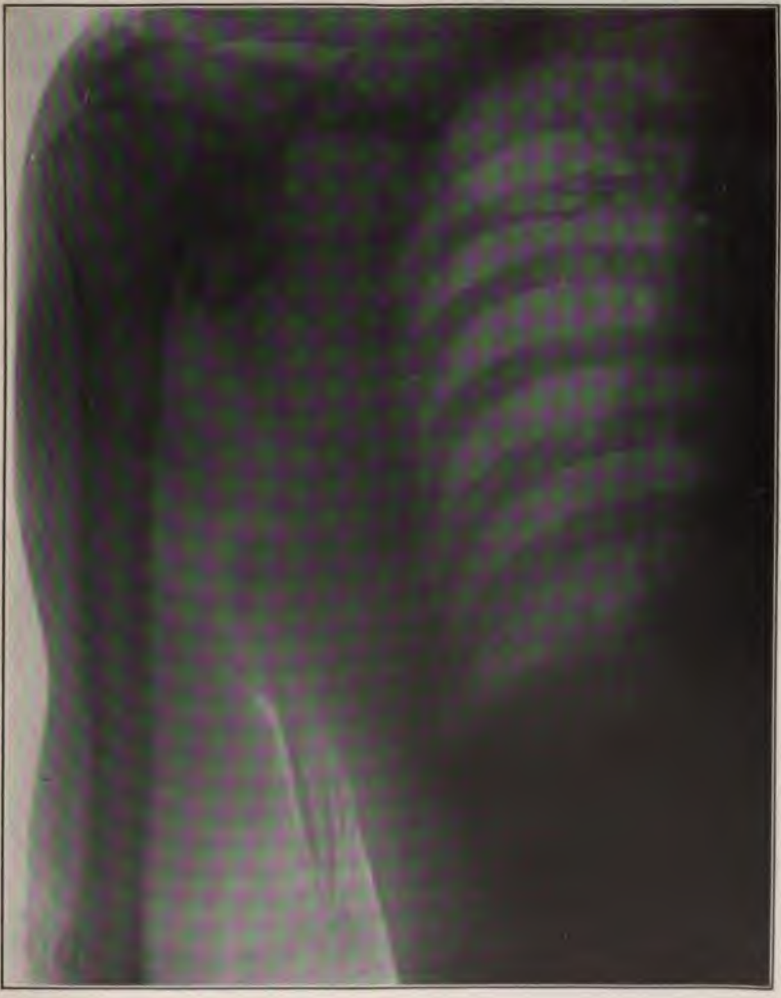

PLATE V.

Fracture of the Neck of the Scapula; also, of the Second and Third Ribs.

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23. Inflammatory processes, like *spondylitis*, can be differentiated from fractures of the spinal column. Tubercular foci in the vertebræ are also demonstrable. The same applies to osteomyelitis and necrosis.

24. In Plate V, showing fractures of the neck of the scapula, fractures of the second and third ribs are also evident. The diagnosis of these simultaneous injuries were not made because the swelling and crackling of that region, so near the seat of the main injury, were attributed to it. There were no physical signs present and the subjective symptoms consisted in pain that was thought to be caused by the scapular injury. The slight cough noticeable now and then was explained by bronchitis, from which the patient had suffered before he sustained the injury.

25. **Fractures of the Clavicle.**—Fractures of the *clavicle* are, in general, easily recognized, but there are rare cases of impaction and fissure in which no deformity or crepitation is observable, and which could not be recognized except by the aid of the rays. In case of extensive displacement, it is important to control the treatment by repeated observations.

26. In tumors of the chest wall (fibroma, osteoma, chondroma, osteochondroma, osteosarcoma, etc.), the question as to how far the pleuræ and lungs are involved, is of great importance and may determine whether removal still offers any hope of benefit for the patient. The same may apply to advanced carcinoma mammæ, which, thanks to the wonderful advances of surgical science, are rarely seen at the present time.

27. The outlines of the heart are more marked during fluoroscopy than in skiagraphy, its regular contractions producing a diffuse shadow on the plate.

28. In fluoroscoping, the regular expansion of the thoracic walls during each inspiration can be studied, the ribs diverging from each other and the diaphragm descending. The movements of the heart can be distinctly seen. The observations of Williams and Benedikt not only proved some physiological errors in regard to the mode of contraction of the heart, but also cleared some obscure points. That the heart does not empty itself completely at each systole, becomes evident by the presence of a large blood shade. Thus we learn that the contractions of the heart are not of the extent assumed heretofore. In proportion to the amount of blood filling the ventricles, the shade of the apex appears lighter or darker.

During deep inspirations it can be observed that the diaphragm becomes distant from the heart, which proves that the heart is suspended by its blood-vessels and is not supported by the diaphragm.

The importance of ascertaining the exact size of the heart should also not be underestimated. For examination in this direction, at least two skiagraphs, under different projection planes, should be made in order to avoid errors. The principles of localization should be well observed.

29. Mediastinal Tumor.—As to type, shape, and size of any mediastinal tumor, much more reliable information can be obtained by skiagraphy than by percussion. In the case of a patient, age 53 years, the symptoms of esophageal stenosis became apparent, the esophageal sound stopping at the level of the fifth dorsal vertebra, and signs of cachexia showing, carcinoma of the esophagus was thought of, and the question of operative interference arose. The skiagraph showed a mediastinal tumor of the size of a new-born child's head that pressed upon the esophagus. Therefore an operation was not expected to be of any benefit. The autopsy verified the diagnosis 5 weeks later.

30. Stenosis of the Esophagus.—To localize stenosis of the esophagus, a rubber tube containing thin, flexible steel wire in spiral form, may be used, the skiagraph demonstrating where the stoppage of the tube occurs. Most patients, however, will not tolerate this otherwise effective procedure.

For fluoroscopic examination, it is advisable to administer an opaque substance, like subnitrate of bismuth, in a wafer. The tube is adjusted in front of the patient's right shoulder in such a manner that the chest is irradiated from the right upper anterior aspect toward the left lower posterior. The bismuth

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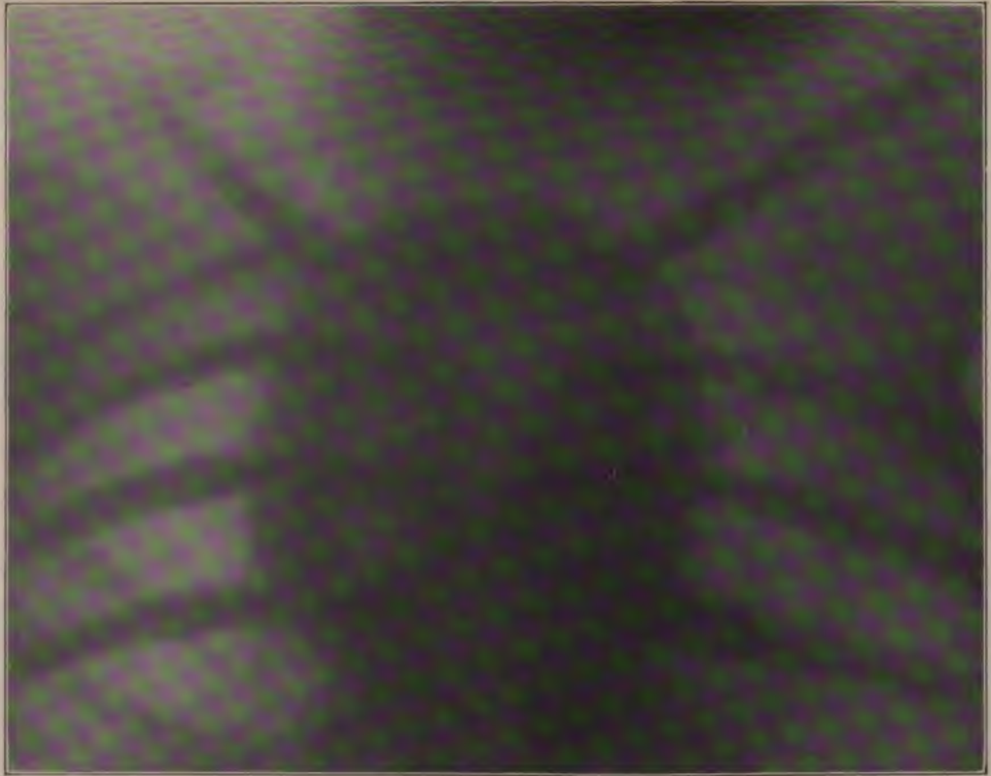

PLATE VI.

Aortic Aneurism.

(about 15 grains) can be seen during the act of swallowing as a marked shade that becomes diffused after a few seconds; then a portion of it is detected in the stenosis, while the other esophageal parts show nothing abnormal.

31. In a patient, age 65 years, asthmatic symptoms were in the foreground. Percussion and auscultation showed dullness of the left side reaching from the lower border of the third rib to 2 inches below the arch of the ribs.

There was slight bruit, but no visible pulsation. Deglutition was slightly interfered with. The patient was thin, but apparently there was no cachexia. The skiagraph showed a tumor occupying nearly the entire left thoracic cavity. The irregular outlines, together with the absence of pulsation, pointed to the presence of a solid tumor. The autopsy, made 2 months later, showed an enormous sarcoma of the bronchial glands.

32. Aortic Aneurism.—Aortic aneurism can also be advantageously studied. In the case of an Italian laborer, a pulsating tumor was detected at the left intraclavicular fossa. The diagnosis, aneurism of the subclavian artery, had been made and ligation advised. In the meanwhile, several skiagraphs were taken that showed the presence of aortic aneurism, the supraclavicular tumor only being a portion of it. Iodid of potassium was administered and the supraclavicular tumor disappeared entirely. The size of the aneurism had considerably decreased, as was shown by the skiagraph. In harmony with the anatomic diagnosis is the excellent condition of the patient, who has been under observation for a year.

33. It should be borne in mind that under normal circumstances the aorta is seen in the left mediastinum at the first intercostal space. A sac-like bulging of the arch, showing considerable pulsation above this space, points to the presence of aortic aneurism. Vehement pulsation, if there is no sac-like bulging, points to aortic insufficiency.

In a most extraordinary case of aortic aneurism, it was possible to demonstrate not only complete atrophy of the sternum down to the xiphoid process, and of the sternal portions of the clavicle, but also the overlapping of the heart over the parasternal line and the downward displacement of its apex. The oval shape of the heart was distinctly seen and was easily distinguished from the aneurism, the enormous intrathoracic extent of which was clearly shown. Another skiagraph of the same case showed the aortic arch. The patient succumbed to pneumonia 6 months after his case was demonstrated. The diagnosis was verified by the autopsy Plate VI.

If we realize that the rays enable us now to recognize aneurisms at their earliest stages, it becomes evident that frequently a series of prophylactic measures can be used that may counteract any further aneurism formation. The therapeutics then being under perfect control, it can be ascertained whether, under treatment, either improvement, arrest, or still further expansion may take place.

34. Arteriosclerosis.—The diagnosis of arteriosclerosis, while very easy on the surface of the body, was very difficult in the deeper tissues. According to the textbooks on internal medicine, the thickening of the tunica intima cannot be recognized if it be confined to a small area or to single small foci. It hardly need be emphasized how important it is to know whether, in a given case of sclerosis of the radial artery, there exist foci in other vessels. Nor can it be a matter of indifference what may be the number of these obstructive foci, and whether a large artery, such as the aorta, or only a small one, such as the temporal, is concerned. The presence of a large number of foci means a loss of propelling energy in the circulation, which can be compensated only by the increased working power of the left ventricle. The arterial pressure thus becoming higher, hypertrophy of the overworked ventricle will be the most natural consequence. If such foci are recognized at an early stage, proper prophylaxis can accomplish a great deal in preventing secondary disturbances. The prognostic significance of an exact knowledge of the condition of the arteries is also evident. The Roentgen rays give us a more reliable method of ascertaining the condition of the vessels, and this in nearly every part of the body. So-called intermittent

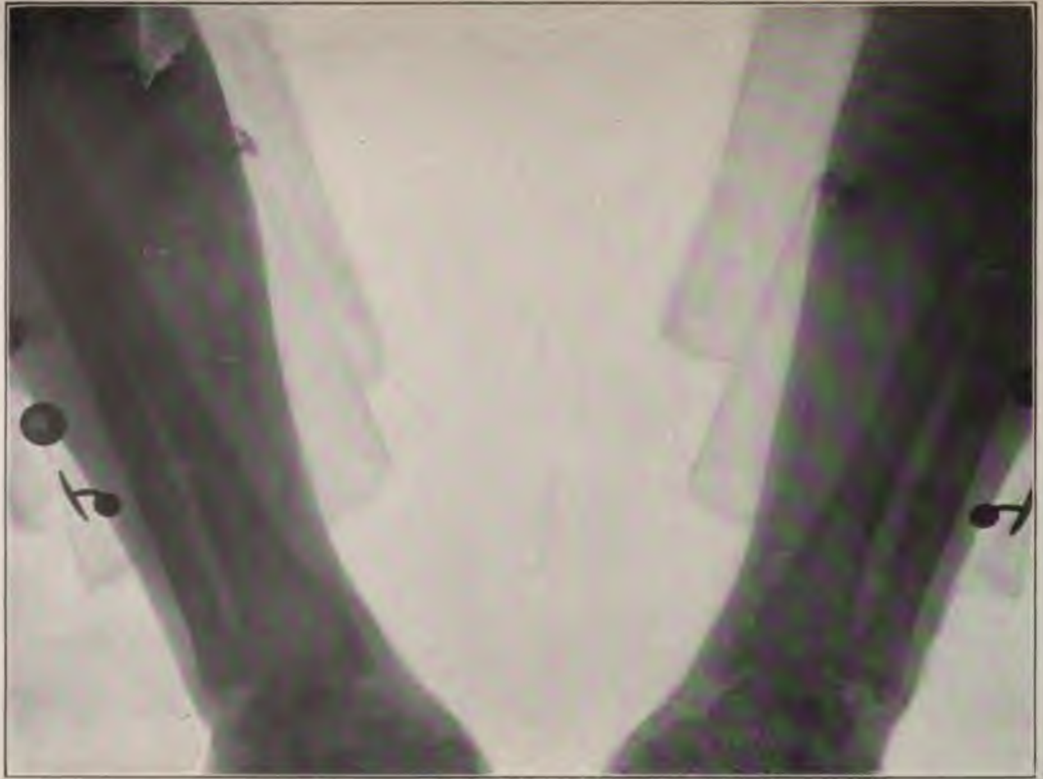

PLATE VII.

Arteriosclerosis.

limping is thus sometimes explained by the early recognition of sclerosis of the arteries of the foot.

In a case of sclerosis of both radial arteries, Plate VII, the forearm, head, neck, femoral, and aortic regions were studied skiagraphically. Nowhere did the conspicuously developed plates show any indications of degeneration of any artery except on the forearm. From the negative state of the other skiagraphs the conclusion was drawn that the patient's arteriosclerosis was confined to the radial and the anterior interosseous arteries—a limitation that harmonized with the good general condition and absence of palpitation, dyspnœa, and vertigo.

35. Skiagraphing Arteries.—The arteries can be well represented on the cadaver, after they are injected with a material not permeable by the rays, as, for instance, a mixture of calcium sulfate or of blue ointment of 33⅓ per cent. Thus a representation of the smallest arterial branches can be obtained and images of the arterial branches of the lungs, kidneys, spleen, and the brain can be beautifully represented by a stereopticon.

36. As to type and size of mediastinal tumors, much more reliable information can be obtained by combined fluoroscopy and skiagraphy than by percussion and auscultation. The examination must be made in different positions. While aneurisms, as stated in Art. **32**, are characterized by the presence of pulsations, and mediastinal tumors by the absence of pulsations, it should not be forgotten that mediastinal tumors may also appear pulsating, the pulsation being communicated. On the other hand, there are aneurisms that do not pulsate.

37. Pericarditis. — Pericarditis is not infrequently observed after a fracture of the ribs if a splinter has pierced the pericardium. The true character of the trauma can always be elicited by Roentgen rays. If, for instance, the clinical symptoms are slight, and the rays show no displaced splinters in the direction of the pericardium, medical treatment alone is in order. Even if a bullet, after having fractured a rib, has entered the pericardium, there may be no need of surgical interference if no severe symptoms are present.

In the case of a man that was shot through the supraclavicular fossa, in a perpendicular direction, 8 years before he died, the bullet was detected by the fluoroscope at the apex of the heart. No apparent disturbance had been caused by it. At the autopsy, the bullet was found embedded in fibrous tissues in the pericardium.

The evidence of a sharp bone splinter pointing toward the pericardium indicates the urgent necessity of exposing the pericardial sac after the resection of the left fourth, fifth, and sixth ribs. They do not necessarily need to be resected in their totality, but may be folded up at their sternal junctions like a bone flap of the skull. The diagnosis of pericardial adhesions may also be verified by fluoroscopy, which shows limited expansion.

DISEASES OF LUNGS AND PLEURA.

38. In regard to the study of the diseases of the lungs and pleura, whoever does not master the principles of auscultation and percussion is not fit to comprehend their fluoroscopic or skiagraphic signs. There are conditions in these organs that can be better elicited by the so-called physical methods and others that can be ascertained only by means of the Roentgen rays. While the rays show small tumors or infiltrated foci that, on account of their central location, cannot be diagnosed by the old physical methods, they have the disadvantage always to show the thoracic image *in toto*, that is, they represent all the shades of the tissues situated before and behind the diseased area at the same time, while the result of percussion and auscultation is circumscribed.

39. Tuberculosis.—At the early stage of tuberculosis of the lungs, valuable information can be derived from irradiation. Skiagraphy is of greater value in this connection than the study with the screen. Solidification and atelectasis, as well as exudation and calcification, can be well demonstrated. The true nature of the various shades is often better understood if, after skiagraphic representation, the thorax is also fluoroscoped in different positions.

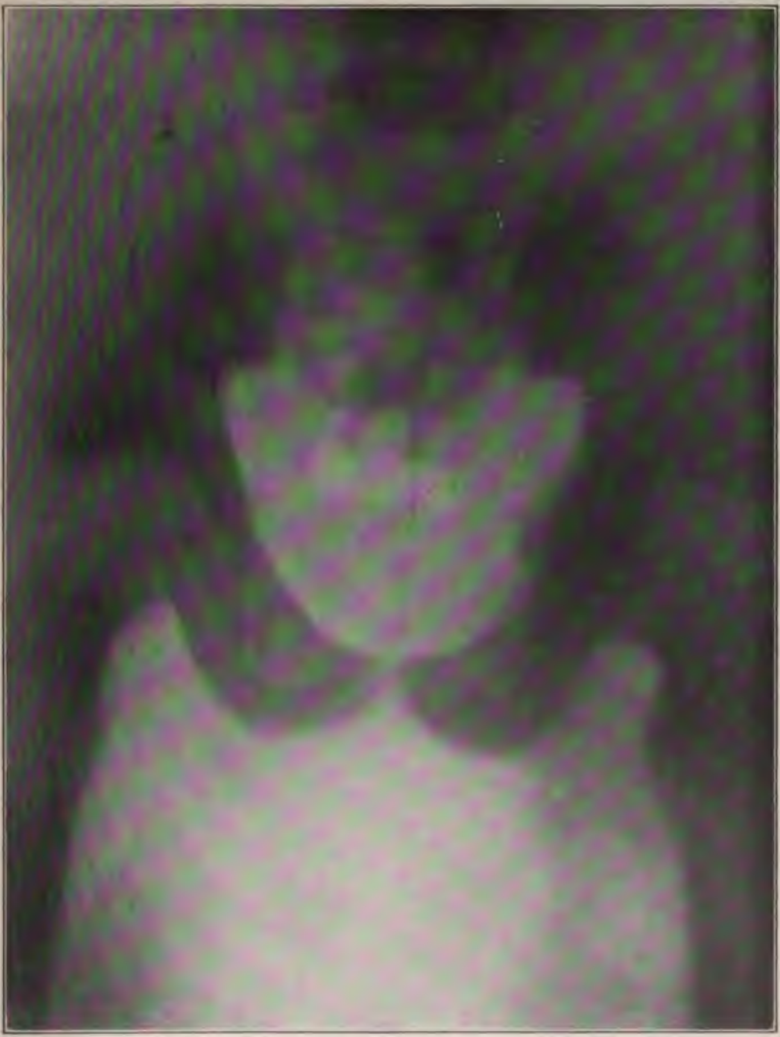

PLATE VIII.

Fracture of Ileum.

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40. Thus interlobular exudation may be differentiated. The localization of *lung abscess,* of echinococcus and gangrene of the lungs, etc. is simplified by examining in different positions. Abscesses and gangrene of the lungs appear as light circumscribed foci that contrast markedly with the darker shades of the lungs.

41. Pleuritic effusions show a marked opacity through the fluoroscope. The larger the amount of effusion, the greater is the degree of opacity. In *pyothorax* the opacity is somewhat less complete than in serothorax. Especially on the right side the outlines of the liver show a marked contrast to the lower boundary line of the effusion. The inner boundary line of the effusion generally appears convex, but if the patient inspires deeply or if he coughs violently it loses its convexity and becomes horizontal. By changing the position of the patiënt, of course, displacements of the effusions are observed accordingly. Uniform transparency above the effusion points to the result of a simple inflammatory process, while constant opacities of an irregular appearance justify a suspicion of a beginning of tuberculosis.

42. As a rule, it is found that the area of dullness corresponds to the area of shadow. It is natural that the representation of cavities in tuberculous lungs should not be attended with any technical difficulties. Mediastinal and pulmonic tumors, which, on percussion, did not show any dull area pointing to their presence, are recognized. Swollen bronchial glands have also been diagnosticated by the rays. Hypertrophied pleuræ show a very distinct shadow according to the thickness of their tissues.

43. The extent of a pyothoracic cavity can be represented by filling it with iodoform glycerin. The subnitrate of bismuth, which is not permeable by the rays, furnishes a still more marked contrast; but, as it interferes with the treatment, its use cannot be recommended for this especial purpose.

44. The rays also proved that after subperiosteal resection of a rib, the exsected portion is always more or less reformed.

45. *Hydropneumothorax* may also be recognized by the rays, which show the very dark outlines of the exudation in contrast to the light shade of that intrathoracic area that contains air. The dark boundary line of the exudation can be recognized by the fluoroscope as an ascending and descending line during respiratory movements.

46. Localization of *bullets in the thoracic cavity* is not always easy. The temptation to extract bullets that cause no disturbance has been greater than formerly, a fact that is not to be registered among the advantages of the Roentgen rays.

Nowhere is the necessity of careful interpretation of skiagraphs so apparent as in thoracic diseases. It is utterly impossible to instruct a non-medical skiagrapher and to impress upon him the necessity of emphasizing certain points. If the physician does this work himself, he will be able to judge much better. But even then a great deal of doubt as to the real nature of an abnormal shade may exist. The scientific physician must never be tempted to tax his power of imagination, but must base his diagnosis on all the methods at his command, of which the Roentgen rays, however, form an integral part.

ABDOMEN.

47. The **abdomen** is best fluoroscoped while the patient stands, and is skiagraphed easiest and best in the abdominal or dorsal position. The study of the abdominal organs, however, leaves much to be desired. The solid mass of the liver can be easily represented, while intestinal loops are only sometimes well shown. The intestinal contents, especially those of the transverse colon, are recognizable. The outlines of the stomach can be made visible by substances impermeable by the rays. The spleen and kidneys are rarely demonstrated at the screen, but can be outlined by skiagraphy. Below the shade of the liver, especially of its left lobe, the lower ribs are markedly seen. The triangular shade of the psoas muscle, from the beginning of the twelfth dorsal vertebra, is always easily recognized.

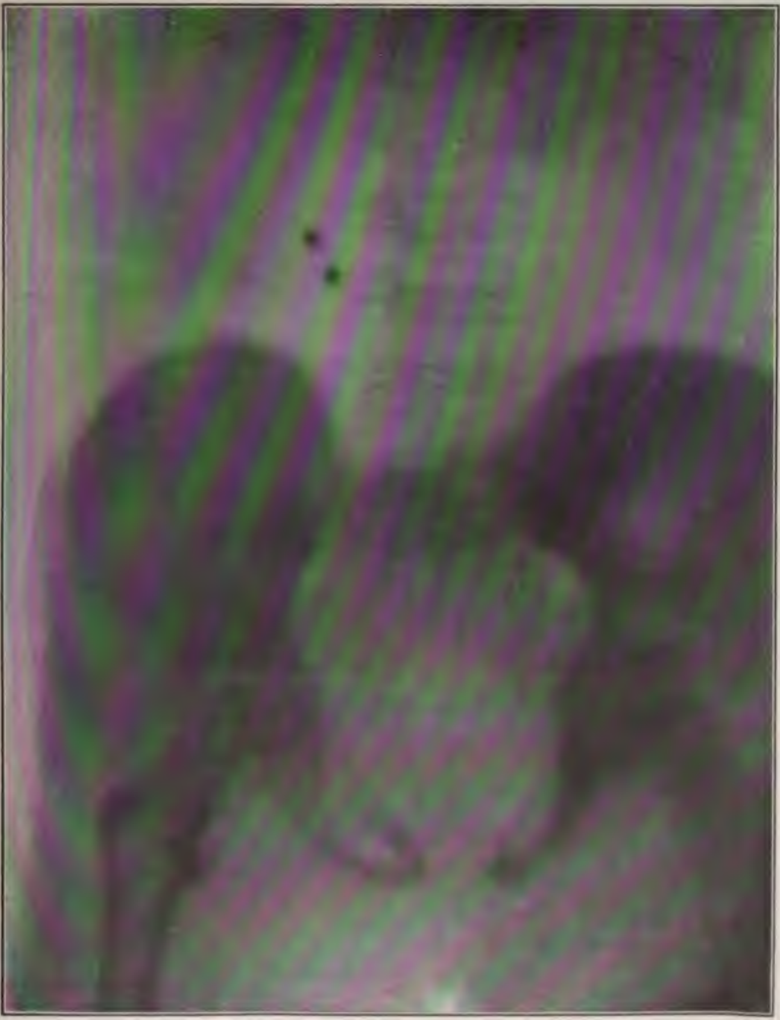

PLATE IX.

Ureteral Calculi.

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48. Principal Benefits of Abdominal Skiagraphy. The main practical benefits in abdominal skiagraphy have so far been derived from the representation of the injuries and diseases of the lumbar vertebræ, and of concretions and foreign bodies. Thus fractures, dislocations, inflammatory processes, and growths of the lumbar vertebræ can be diagnosed as well as calculi of the kidneys, ureters, bladder, prostate, urethra, gall-bladder, and the hepatic ducts.

49. Skiagraphing the Liver.—The liver is best represented in the abdominal posture. In new-born children its shade is especially well pronounced. The position, size, and shape may give valuable information in many obscure hepatic ailments.

The diagnosis of *subphrenic abscess* is simplified by fluoroscopy as well as by skiagraphy, the space between the diaphragm and the lower boundary lines of the abscess showing distinctly.

50. Total *transposition of the viscera* was well represented in Annals of Surgery, May, 1899. Never before has cholecystotomy for cholelithiasis been performed on the left side, as it was done in this remarkable instance. The greatest usefulness of the rays in hepatic diseases is, however, displayed in the recognition of cholelithiasis.

51. Skiagraphing Gall-Stones.—Gall-stones could not be skiagraphed until recently. It was our privilege to show the first undisputed skiagraph of gall-stones in the living subject at the October meeting of the New York County Medical Association, in 1899. Gocht, Oberst, Rumpf, Dumstrey, and Metzger, who are among the best known experts in skiagraphy, declared until recently that biliary calculi could not be represented. The last-named is even responsible for the bold assertion that "nowadays nobody will any longer maintain that gall-stones can be skiagraphed"; that "all experiments in this direction have proved to be failures"; and that "it appears hopeless that such experiments will give any other result in the future." But *errare humanum est!*

After many trying disappointments, we succeeded for the first time in skiagraphing the cholelithiasis of a woman 72 years of age, after having used four different photographic plates at the same time. The upper plate, situated directly below the region of the gall-bladder, clearly showed the outlines of the liver, while in the fourth and most remote plate it appeared only faintly, but the calculi were clearly represented. The next exposure was made with a powerful tube on a single plate, and lasted 10 minutes. After it was found how long it took with this tube to represent the liver and the os ilii, a second plate was exposed, this time for 6 minutes only. This second skiagraph showed the denser tissues less clearly, while the calculi were much more distinct. An exposure lasting 7 minutes, one for 8 minutes, and one for 9 minutes were also made, all showing that the longer the time of exposure, the clearer the denser tissues and the more obscure the calculi appeared. It thus became evident that one exposure was not sufficient to determine the length of time required by each *individual* tube for the representation of each individual gall-stone type. This suggested that a test should be made first by making a short, as well as a long, exposure in a case of suspected cholelithiasis; that is, an exposure of about 4 minutes, as well as one of 9 or 10 minutes. The most powerful tubes at present attainable should be chosen for this purpose. By comparing the results, the proper time of exposure for the best results can be estimated. For better identification, the contours of the organs, especially the liver, should be outlined by thin wire attached to the plate before the final skiagraph is taken.

52. The results, of course, are to a great extent dependent on the chemical composition of the biliary calculi, which is far more complex than those in the urinary tract. All the different types of calculi can be skiagraphed on a photographic plate. In this way we obtain a visual comparison of their permeability. The same calculi can then be irradiated through the living body, thus practically demonstrating the difference in translucence. The common biliary calculi, the most frequent type, are found to be quite permeable to the rays, and therefore produce only

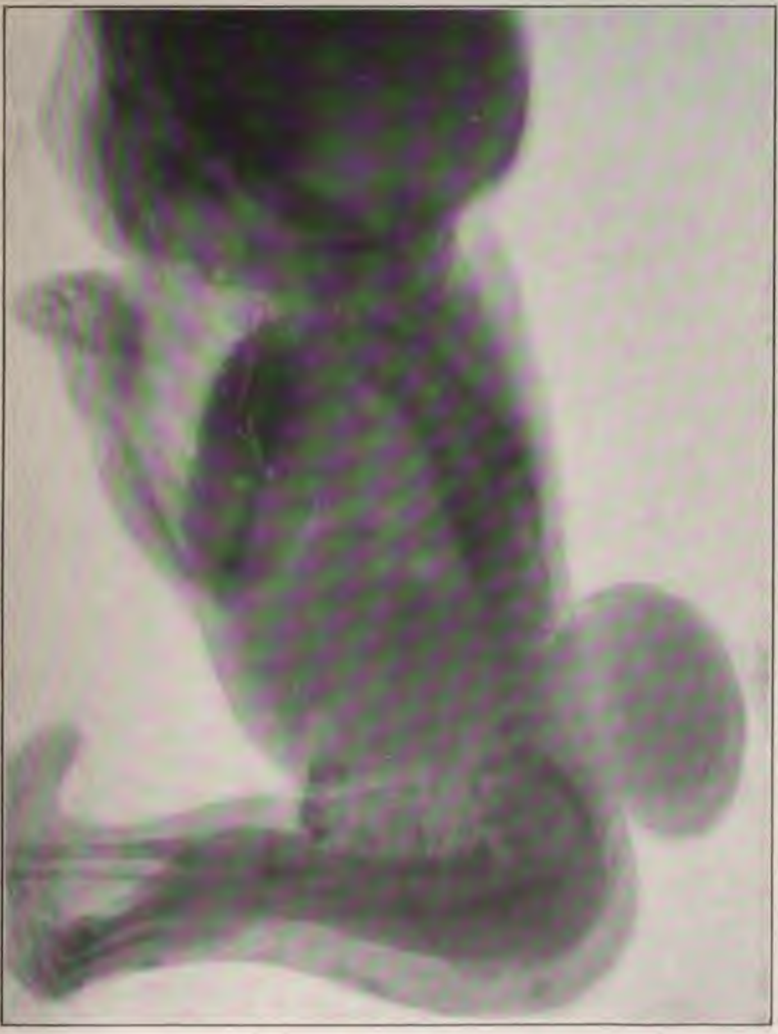

PLATE X.

Spina Bifida.

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a light shade. If present in large numbers, the shade is somewhat more conspicuous. Calculi composed of pure cholesterin are less permeable than the common type and show a slightly more distinct shade.

The stratified cholesterin calculi, on account of their admixture with calcium, show much less permeability, and therefore produce a distinct skiagraph. The mixed bilirubin calculi, which, besides bilirubin-calcium, contain traces of copper and iron, are less permeable than all the former varieties and consequently give a very distinct shade. The same applies to the pure bilirubin-calcium calculi.

Calculi composed of pure cholesterin, on account of their mixture of calcium, show less permeability by the rays. In consequence, their outlines can be nearly as distinctly shown as those of the bilirubin-calcium calculi. But with an excellent tube, even the more translucent calculi can be represented. Recently, calculi that were only the size of a pin-head were shown in the gall-bladder. Calculi of the hepatic ducts were also represented.

TUBES USED.

53. Selecting the Tubes.—These results, which could, formerly, hardly have been hoped for, are attributed mainly to the excellent qualities of the tubes used and their careful selection. They must be carefully studied, individualized, so to speak, as different patients are to be judged differently although suffering from the same disease.

The most important requisite for skiagraphic success in such delicate work is a strongly built and powerful tube, one that will bear a 15-inch spark for about 5 minutes without becoming too hot.

Another important requirement of such tubes is that they be of medium hardness, so as to permeate the soft tissues without penetrating the dense tissues. A tube useful for that purpose can best be tested by the operator's own hand. In fact the hand is a better indicator than any artificial skiameter, as it contains many types of bones, from the massive carpal end of the radius, to the delicate third phalanx of the little finger.

If the bones of the operator's wrist, especially the lower radial epiphysis, appear grayish-black, but still as well-defined structures, while the soft tissues show but lightly, the tube is fit for a fair production of biliary calculi.

It has been found that the tubes used for the reproduction of biliary calculi display their energy only so long as they are comparatively new. Later on, they show less contrast, just like very hard tubes, even if provided with an attachment for regeneration.

54. Time of Exposure.—If the tube works well from the beginning, the time of exposure should be about 5 minutes in thin individuals and about 7 in stout ones, provided Cramer's, Carbutt's, or Schleussner's plates are chosen. The best results were obtained from the 8″ × 10″ Cramer plates.

55. Position of Patient.—The position of the patient while being skiagraphed is also an important factor. He should lie on his abdomen with about three pillows underneath his clavicles, as the elevation produced permits the protrusion of the gall-bladder, thus bringing the calculi nearer the photographic plate. The approximation is increased by turning the body slightly to the right and raising the left side.

56. Direction of the Rays.—Another point of importance is, that the rays should not penetrate the abdomen in a vertical direction, but from the side, so that the thick and less transparent tissue of the liver is not permeated in its whole diameter. The direction of the rays should be such that they form an angle of about 70° with the plate. The nearer the tube is to the plate the more distinct will be the picture. As only a small area shows distinctly on the plate, great care must be taken to place the tube in the proper direction. A pencil mark should be made on the back to correspond to the site of the gall-bladder in front.

The disadvantage of oblique irradiation is that the calculi appear nearly twice as large as their normal size. When a protrusion palpable in the region of the gall-bladder indicates that it projects from the liver, direct irradiation is to be preferred, which magnifies to about 30 per cent. In order to

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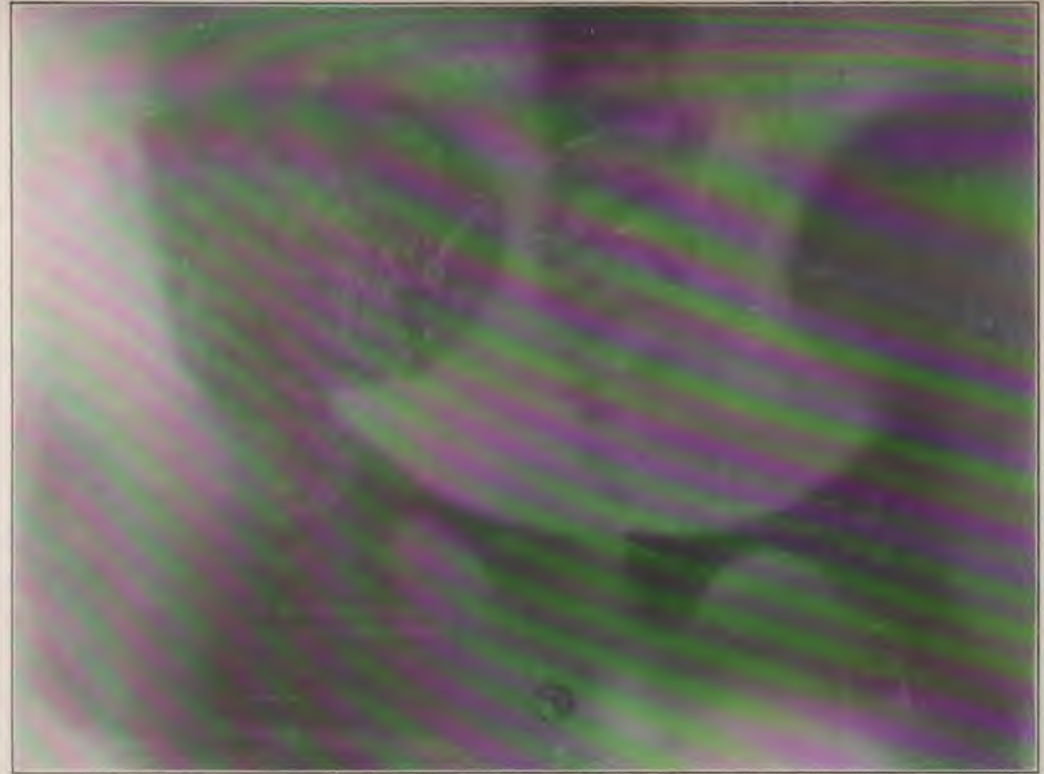

PLATE XI.

Rachitic Pelvis.

exclude any possible source of error from intestinal contents, the bowels must be thoroughly evacuated before irradiation.

By using this method, not only can the size, shape, and diameter of the gall-stones be determined in suitable cases, but they can also be localized. The importance of knowing whether there are also calculi in the liver besides those present in the gall-bladder, needs no discussion.

57. Calculi in the Liver-Tissue.—The presence of calculi in the liver-tissue explains why cholelithiasis is often only partially cured by cholecystotomy. This fact shows why calculi have sometimes surprised the surgeon, who has thoroughly evacuated the gall-bladder, by their appearance a few days after cholecystotomy. That in cholelithiasis sometimes hundreds of calculi are contained by the hepatic ducts is a well-known fact, but why calculi appeared after cholecystotomy has heretofore been ascertained only from the autopsy table.

58. It is evident that a positive skiagraph renders exploratory laparotomy for suspected cholelithiasis unnecessary. It can be ascertained by subsequent exposures whether any calculi have been dislodged or whether some have escaped. If they are of very large size, their removal by any other than a surgical way would, of course, not be expected. So the question of whether or not an operation is advisable in cholelithiasis may be settled by the Roentgen rays. When only small stones are present, there is a chance for medical treatment. When stones are found too large to pass the common duct, medical treatment can only be of a palliative character, and cholecystotomy should be performed as soon as the calculi prove to be a source of irritation.

A woman, age 73 years, whose calculi were skiagraphed 18 months ago, was reexamined recently. Three skiagraphs, taken at different times and in different positions, showed a negative result. The patient had submitted to diet and the regular administration of Karlsbad Muehlbrunn for more than a year, and the result was that the tumor in the region of the gall-bladder had disappeared. Her general condition had also improved accordingly and no colicky attacks were noted during the last 18 months. One may feel justified in believing that the negative skiagraph confirmed the impression that the stones had passed away.

59. Diagnosing Biliary Calculi.—It is appreciated that the method given for diagnosing biliary calculi is incomplete and needs further modification and improvement, as there are many delicate technical details on the correct appreciation of which success depends. Skiagraphy of biliary calculi is not so perfect a method as that of renal, ureteric, and vesical calculi. While a negative result, in the case of the suspected renal calculi, can now pretty safely be taken as the evidence of the absence of calculi, the same cannot yet be said of biliary calculi.

But, on the other hand, it can safely be asserted that even a faint skiagraphic reproduction of biliary calculi proves their presence to the expert reader. We feel confident that with increased knowledge and improved technique, the skiagraphic reproduction of biliary calculi will soon prove to have become a reliable method.

The outlines of the gall-bladder are often shown if there is cholelithiasis. On account of the long-continued irritation, the bladder walls become thick and fibrous and consequently less permeable to the rays.

60. Skiagraphing Kidneys in Dorsal Position.—The kidneys must be skiagraphed in the dorsal position. Tubes of moderate hardness are best for their skiagraphic representation; very hard tubes penetrate the organs and leave no shade. Renal fluoroscopy cannot be relied on with our present means. Hydronephrosis and echinococcus can be represented under favorable circumstances. The greatest usefulness of the rays in renal disease, however, is displayed in diagnosticating *concretions*. Great credit is due to MacIntyre for having first skiagraphed a renal calculus. Soon afterwards Twain, Thyne, and Kümmell, besides ourselves, obtained distinct skiagraphic representations of nephrolithiasis.

At first it was thought that only such calculi could be represented as consisted of hard and firm material, like oxalates,

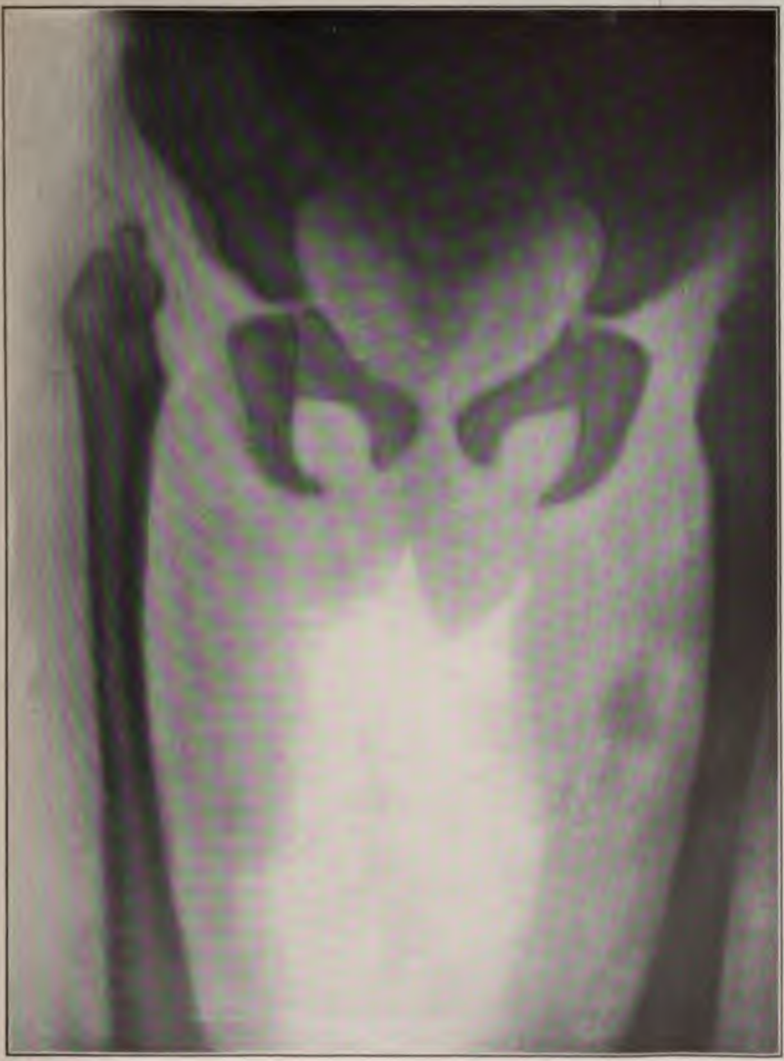

PLATE XIII.

Congenital Dislocation of Both Hips.

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while the more penetrable urates left an indistinct shadow, and the translucent phosphates hardly showed at all. Thus the success of skiagraphy in calculi of the urinary tract seemed to depend only on the different chemical composition of the calculi, and, consequently, on their greater or lesser opacity. Now, with the new powerful tubes, more or less opaque shadows of the three different varieties can be obtained. The beautiful work of Abbe, Bevan, and Leonard, all of this country, furnishes a striking illustration of the immense progress of the young science in the short space of a few years.

61. Technique of Skiagraphy of Concretions of the Urinary Tracts.—As to the technique of the skiagraphy of renal concretions many of the principles emphasized in connection with gall-stones hold good. In regard to their chemical composition, it should be remembered that a calculus may consist of different salts. In a case of Lauenstein, the nucleus of a renal calculus consisted of calcium carbonate, its branches of a combination of calcium carbonate and triphosphate, and the outer crystallin layer of carbonate of magnesia and ammonia.

Under such circumstances, the nucleus would be more marked if a tube of moderate hardness is used, while the branches would be more conspicuous if a softer one was employed. As a rule, tubes should be chosen that are slightly softer than those used for skiagraphing biliary calculi. In other words, they should show the carpal epiphysis of the operator's radius very dark gray.

The time of exposure should be 6 minutes in thin, and about 9 minutes in stout, individuals. A good skiagraphic representation of nephrolithiasis renders an exploratory incision unnecessary. It will naturally settle the question of the presence or the absence of concretions absolutely. In case an operation is indicated, it will also give valuable hints as to the technique.

62. Nephrolithiasis. — While skiagraphing suspected cholelithiasis, a negative result cannot be relied on; a good skiagraphic plate that does not show the presence of renal calculi, may safely be regarded conclusive. The characteristics of a reliable renal skiagraph are that it shows the outlines of the kidney distinctly. And, if the renal outlines show distinctly, a calculus contained by them would necessarily also leave its shade on the plate, because it is less permeable to the rays than is the renal tissue.

Regarding the high mortality of nephrolithiasis at a late stage, it becomes evident how many lives will be saved by early operation. But this is possible only by early recognition of the calculi and the only method that permits this is skiagraphy.

In interpreting skiagraphs taken for suspected nephrolithiasis, it should be borne in mind that under extraordinary circumstances biliary calculi may be taken for renal calculi. It may be said, however, that, as a rule, the shape of the biliary calculi is different from that of the renal; they are also located higher up and do not show as clearly from the back as they do from the front. Of course, in those cases where the shape of the kidney is well marked, the shade of the renal calculus will hardly be misinterpreted. In a case of doubt, a lateral exposure will show a renal calculus in the back, while the gall-stones would appear in front. The clinical symptoms should also be properly considered before conclusions are drawn. Just as in cholelithiasis, the skiagraphic proof of the presence of small calculi shows that there is a great chance for medical treatment, while the removal of large calculi cannot be expected by any other than surgical means. The distance of the tube from the plate in skiagraphic representations of the kidney should be about 50 centimeters.

63. Ureteral and Vesical Calculi.—Ureteral and vesical calculi can be skiagraphed after the same principles. Difficulties arise only in stout individuals. A vesical calculus shows best in the abdominal position the center of the tube to be directed to the upper margin of the symphysis pubis. Any vesical calculus, be it ever so small, will surely be evident on a good skiagraph. A lateral exposure should always be made besides, because it shows whether the stone is free or encysted. If the patient bends slightly forwards in the lateral position, the calculus, if free, sinks towards the anterior vesical wall and

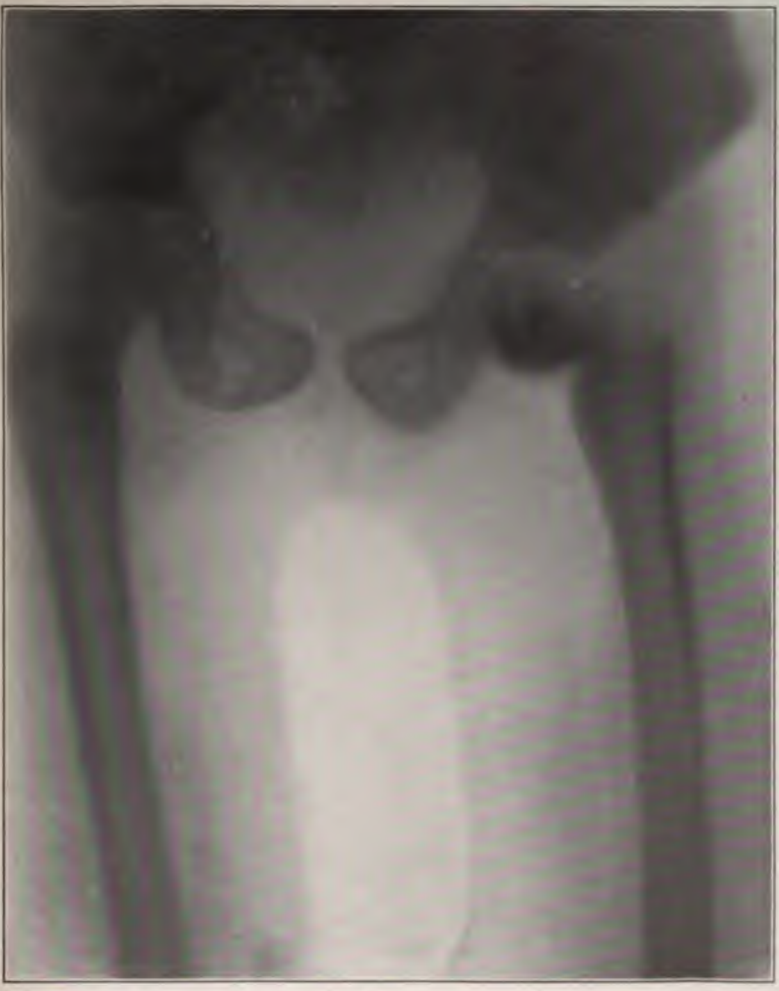

PLATE XIV.

Fracture of the Neck of the Femur in Girl of 14 Years.

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becomes conspicuous directly behind the abdominal wall. If not, it usually shows far back toward the sacrum, since encysted calculi are nearly always attached to the posterior vesical wall. If very large stones or a large number of them are present, the whole space, of course, is filled up and displacement is not apt to occur.

In a boy of 6 years, who, besides frequent micturition, did not present any signs of vesical calculus, the stone-searcher did not reveal the presence of a calculus, while the skiagraph, although the restless patient had moved considerably during examination, showed a calculus 2 inches in length and ¾ inch in diameter. The spinal column, the sacrum, ileum, and pubes appeared much distorted, and the vesical calculus produced less shades of the calculus, but even this poor skiagraph proved to be correct at the subsequent extraction of the calculus, done at St. Mark's Hospital. The skiagraph, taken in the lateral position, showed the calculus far back near the sacrum; thus its tight attachment to the posterior bladder-wall was anticipated. Superpubic cystotomy proved the calculus to be deeply imbedded, the mucous membrane of the bladder surrounding it nearly, so that its removal was associated with technical difficulties. The stone consisted of oxalate of lime. The patient made a good recovery.

As far as the diagnosis of the number, shape, and position of vesical calculi is concerned, Roentgen rays are a much more valuable support than the cystoscope. The time of exposure should be about 5 minutes. A medium tube is best chosen.

Plate IX represents the case of a lad of 11 years who suffered from the characteristic colicky pains of nephrolithiasis, the seat of maximum intensity shifting downwards in the direction of the ureters.

64. Foreign Bodies in the Abdomen.—Foreign bodies in the abdomen are, of course, easily demonstrated. As modern surgery makes immediate laparotomy imperative in all bullet wounds of the abdomen, it may be realized how important is skiagraphic localization. Tacks and needles can be easily localized. The popularity of the Murphy button gives frequent opportunities to observe its characteristic shadow while it travels through the intestinal tract.

65. Tumors of the Stomach.—Tumors of the stomach are representable according to their degree of density. The outlines can be mapped out, if the stomach is filled with salts that are impermeable to the rays—subnitrate of bismuth, for instance. We, however, prefer the introduction of a soft-rubber tube, the lumen of which is filled with mercury. Of course, in a tube of this kind an eye must not be cut out. A rubber tube containing a thin, flexible-steel wire in a spiral form permits the rapid representation of the outlines of the stomach. The stoppage of this tube indicates its arrival at the large curvature of the stomach, and further propulsion shifts alongside its wall. There the steel spiral is easily shown by the skiagraph.

Inflation of the stomach by carbonic acid, by air, and a mixture of tartaric acid and bicarbonate of soda, have also been used to determine its outlines. The large and small curvatures, as well as the cardia, can thus be represented. The infantile stomach is especially fit for skiagraphic representation. In selected cases, the relations, especially the motions of the spiral wire, are to be studied by the aid of the screen. Tubes of medium hardness should be chosen.

66. The principles of diagnosticating injuries of the lumbar vertebræ are essentially the same as those governing the injuries of the dorsal vertebræ (see Art. **21**).

67. Diagnosing Spina Bifida.—The diagnosis of the various types of spina bifida have also been simplified by the rays. It was sometimes impossible to differentiate simple meningocele, myelomeningocele, and myelocystocele. Especially, the distinction between meningocele and myelocystocele has been generally impossible. Considering only the one point that in meningocele aspiration should be tried first, while in the other varieties extirpation must be resorted to, the importance of the question is self-evident. The skiagraph now shows, with absolute distinctness, whether or not there is an opening in the spinal column; it shows, also, the presence or absence of the

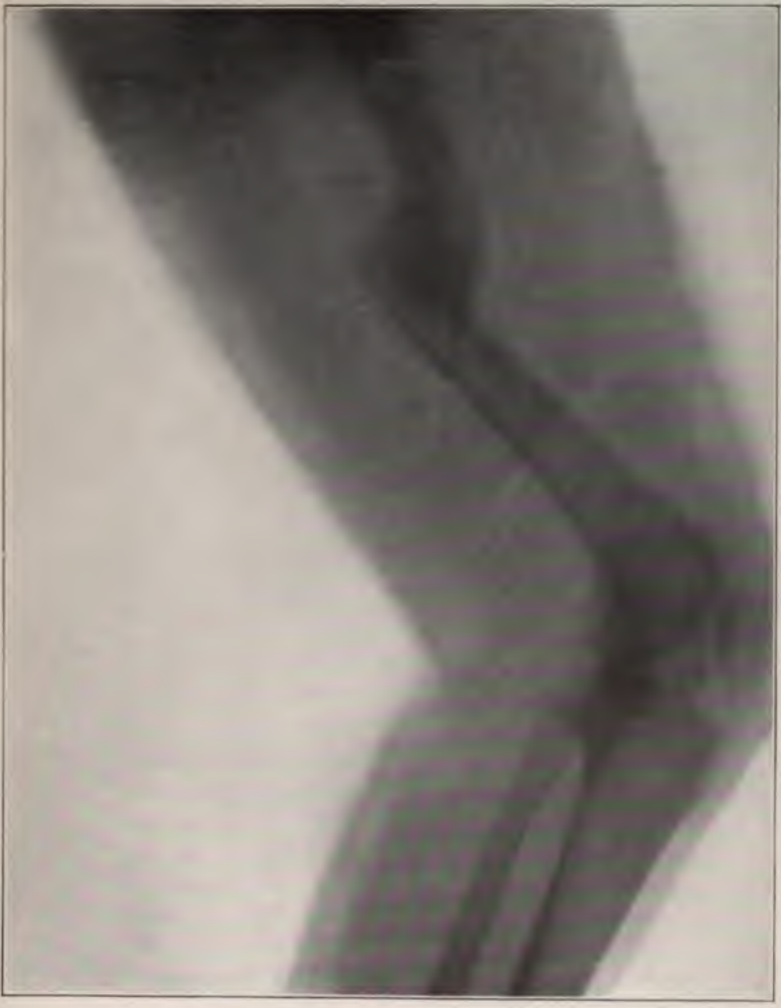

PLATE XV.

Malunion of Middle of Femur in Woman of 26 Years, Which Caused Shortening to the Extent of 3 Inches.

nerve substance, and, sometimes, even its expansion in the sac. In those rare cases in which the presence of fibromyoma is in question, it is the skiagraph that gives the needed information. Plate X.

68. The usefulness of the Roentgen rays in *gynecology* is still limited. Many trials have been made to obtain representations of the uterus, but they have always given unsatisfactory results. In a few instances, the gravid uterus and the faint outlines of the fetus could be detected.

69. **Obstetrics.**—In obstetrics the advantages are greater, the important questions hinging on the condition of the pelvis, which permits of the representation of many types of pathological change. Symmetry and asymmetry of the pelvis, ankylosis, changes in the iliosacral joint and the length of the various pelvic diameters can be well shown. In the case of a woman, age 22 years, shown in Plate XI, the rachitic pelvis showed an elliptic shape, which explained fully why she could never be confined in a normal way. A successful Cæsarian section has been performed on her.

If the exposures are made strictly under the same conditions—the same distance of the tube from the plate, in the exact perpendicular direction—the measures of the conjugata vera, the introitus pelvis, and the transverse diameters can also be relied on.

After *symphyseotomy* it can be ascertained whether there has remained any diastasis of the pubic bones. In case there is proof of the existence of considerable diastasis, a second operation may be avoided.

PELVIS AND LOWER EXTREMITY.

70. The *pelvis* is usually skiagraphed in the abdominal, dorsal, and lateral position. Fluoroscopy of the pelvis is but rarely indicated. Irradiation takes place best in the perpendicular direction, the tube being as near as possible and the symphysis ordinarily being regarded as the center. A dorsal, as well as an abdominal exposure, is necessary, as a rule. The best position of the body is when the legs are slightly inverted, heavy sand-bags supporting them. In the abdominal position, the dorsum pedis must also be supported by a sand-bag. Fractures of the pelvis can be easily recognized, and by the location of displaced splinters a conclusion can be drawn of injuries of the intrapelvic organs. Plate XII represents a lad of 12 years that was run over by a heavy wagon, which resulted in distortion of the ankle and fracture of the ilium near the sacro-iliac synchondrosis. The protruding fragment could be felt by rectal palpation and under the guidance of the rays could be properly reduced. (Plate XII has been omitted from this edition.)

71. In *exstrophy of the bladder* the skiagrapher may succeed in demonstrating the extent of the symphyseal gap. After plastic operations the course can be controlled and the result studied by skiagraphic observation.

In a case of exstrophy of the bladder the diastasis of the pubic bones could be well demonstrated. Take the case of the skiagraph demonstrated before the surgical section of the New York Academy of Medicine, March 11, 1901.

72. In the treatment of *congenital dislocation of the hip*, the skiagraph will determine what method of treatment should be chosen, as it reveals the relation between the femur and the acetabulum. If the condition of the latter be unfavorable, bloodless reduction will be impossible, and a cutting operation must be performed. The skiagraph will also show whether reduction of a dislocated hip is successful or not. It is true that after perfect reduction the head of the femur can be felt between the spine and the symphysis in the majority of cases, and also that the characteristic noise can be perceived while the head is jumping over the margin of the acetabulum. But, on the other hand, it cannot be denied that the noise is often indistinct, and that the thickness of the muscles oftimes impairs our judgment, so that it is the skiagraph that gives indisputable information. Plate XIII shows congenital dislocation of both hips in a girl of 12 years. The skiagraph proves the moderate extent of the dislocation, which justified conservative measures; viz., bloodless reduction. This was done under anesthesia and the result, after a year's treatment, is entirely satisfactory.

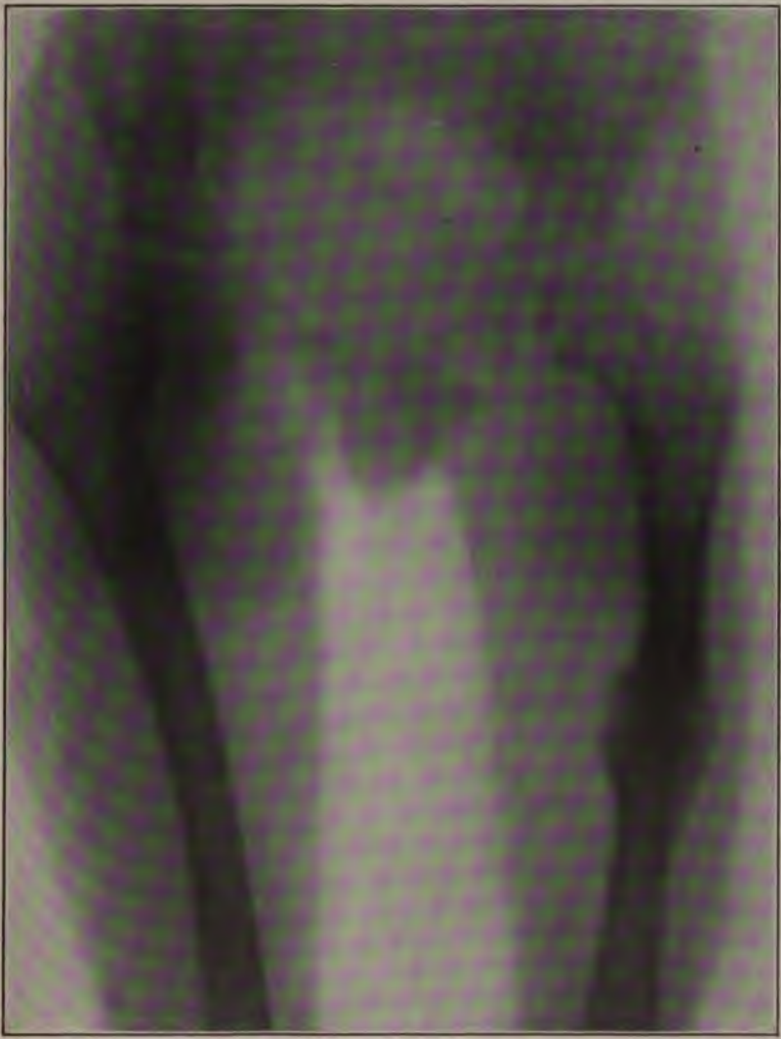

PLATE XVI.

Fracture of the Diaphysis of the Femur in Good Position.

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73. At the early stage of *inflammatory processes* in the hip-joint a correct diagnosis is of the utmost importance. In doubtful cases the rays will determine whether simple, traumatic, or tubercular coxitis is present. In view of the great difference of treatment, the immense importance of a positive diagnosis is evident. It is advisable to skiagraph both hips so that the healthy and the diseased side can be compared.

In a normal hip-joint there is a regular semicircular light area between the femoral head and the acetabulum, while in a tubercular hip the articular outlines, instead of being regular and marked, are irregular and diffuse. Slight projections of the femoral head are often found at an early stage and indicate the presence of fungous granulations. Later on, cheesy foci in the acetabulum, the head, the neck, and the trochanter major are often detected.

Such processes must be differentiated from osteomyelitic foci, which originated within the bone and gradually entered into the joint. That they must be differently viewed is self-evident.

After the healing process is completed, the degree of atrophy of the femur or ankylosis can be well studied.

74. Arthritis Deformans Coxæ.—Arthritis deformans coxæ is characterized by the skiagraphic representation of osseous proliferations from the articular outlines of the head of the femur, the shape of which sometimes reminds one of a papilloma.

75. Fractures of Femur.—It is acknowledged that, in differentiating between fracture of the *acetabular margin of the neck of the femur* and *dislocation and contusion of the hip*, grave errors were committed by the best surgical authorities. The Roentgen rays have caused these embarrassing errors to disappear. Especially has the fracture of the acetabular margin, with its bad functional prognosis, been repeatedly observed, and in some of the instances the diagnosis was not made until the rays were used. On the strength of our more reliable information we were able to remove acetabular splinters with safety, thus restoring functional ability, in two instances. The rays have also shown that a sharp line of distinction between *intra-* and *extracapsular fracture of the neck of the femur* cannot be drawn, and that in the so-called extracapsular variety the fracture line generally extends in the intracapsular region; and vice versa, that in intracapsular fracture the fracture line often extends somewhat outside the joint. The principles of the treatment must be modified accordingly. Plate XIV shows a fracture of the neck of the femur in a girl of 14 years. The fragments being slightly impacted, crepitus could not be produced. Thus the diagnosis would, to the great detriment of the patient, have been imperfect had the rays not disclosed the true character of the injury and enabled us to correct the faulty position.

The skiagraphic proof of the presence of impaction implies the omission of any manipulations, and suggests immediate immobilization in the impacted position. The diagnosis of *isolated fracture of the trochanter major* will no longer be confounded with contusion.

Plate XV shows malunion in the middle of the femur of a woman of 26 years. The ends of the fragments became united in juxtaposition, which caused, shortening of the lower extremity to the extent of 3 inches. It is needless to say that grave functional disturbances followed the injury, which was sustained 2 years before the skiagraph was taken.

In fractures of the *diaphysis of the femur*, which sometimes show an enormous tendency to displacement, skiagraphy should always be used after the application of the immobilization dressing in order to ascertain whether reposition is perfect. It is only thus that a union in a deformed position can surely be prevented. Plate XVI shows the fragments of the fractured femur in good opposition. At the same time an enormous amount of callus is evident from the skiagraph. Palpation alone might have mistaken the prominent callus masses for the protruding ends of the fragments. As to the differential diagnosis between osteomyelitis, osteosarcoma, and aneurism, etc. compare Arts. **130** to **152**.

76. A good skiagraph of the knee-joint illustrates its anatomic relations better than any of the beautiful illustrations in

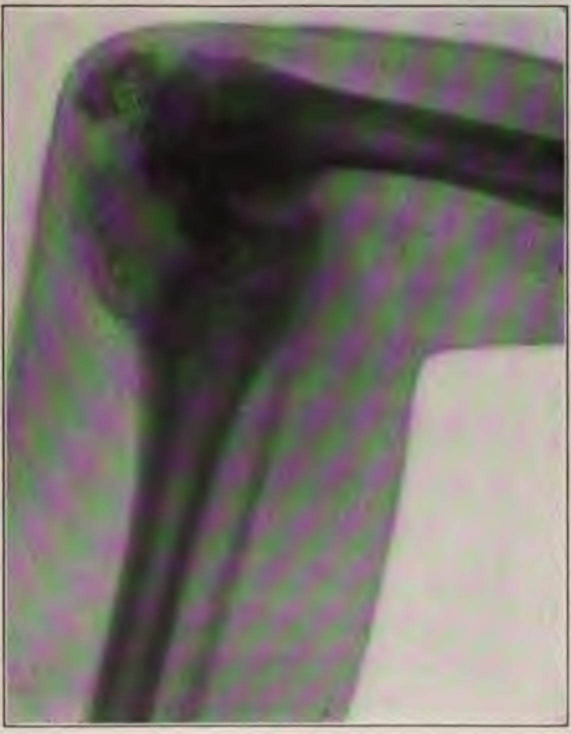

PLATE XVII.

Tubercular Knee-Joint, Dislocated Backwards in Boy of 8 Years.

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the textbooks of anatomy, since they are not depicted from life. Being the frequent seat of simple as well as of traumatic and tubercular inflammations, it offers many indications for skiagraphic differentiation. Recognition of the various injuries of the knee-joint has become much easier, since we are able to show even a displacement of one of the menisci tibiæ. Floating bodies in the knee can also be distinctly located. While the diagnosis of a fracture of the patella by the ordinary method is easy, as a rule, there are instances where contusion or impaction was assumed, but the skiagraph revealed the presence of multiple fractures. It must be borne in mind that the popliteal space often shows a well-defined shade that might be mistaken for a bone fragment or a foreign body, but which, in reality, is a normal *sesamoid* of the *semitendinosus muscle.* This sesamoid is found in about 8 per cent. of subjects examined.

Differentiation between *bony* and *fibrous ankylosis* is now easy. This is most important, since bony ankylosis can only be remedied by separation by the means of a chisel, while in fibrous ankylosis forcible motions can be resorted to.

77. Tuberculosis of the Knee.—In tuberculosis of the knee the healing process can be controlled by the rays after resection as well as after the injection of iodoform ether. While a normal knee-joint shows marked regularity of the outlines of the articular surfaces, the contours of a tubercular knee appear irregular and diffuse. Later on, when cheesy foci have formed, their areas become translucent. The cartilage is sometimes entirely destroyed and shows no shadow. Plate XVII shows the tubercular knee-joint of a boy of 8 years who was treated by a Christian Scientist for 2 years with the result that the cartilages were almost entirely destroyed, so that backward dislocation occurred. The patient had been under our treatment at an early stage of the disease, when conservative treatment would most likely have been successful. But the course of treatment appeared too slow for the parents. When they returned after 2 years it was impossible to treat the case by any other than radical operative means.

78. Foreign Bodies in the Knee.—No attempt should be made to remove a foreign body before its skiagraphic evidence is furnished. Plate XVIII illustrates the case of a man of 20 years that was shot in the middle of the right femur. The patient suffered considerable pain along the thigh and demanded the immediate removal of the bullet. It seems pardonable in this case that the family physician should attempt to extract the bullet without the aid of the Roentgen rays. But the punishment was great. Although the soft tissues were exposed to a great extent from the middle of the thigh down to the knee, the bullet could not be found after a few hours searching. When a skiagraph was taken the bullet was located in the knee-joint near the popliteal space. Extraction could then be performed in a few minutes, a small incision having proved to be sufficient for the purpose. While there was no reaction within the knee-joint, the patient had to suffer for weeks from the large gaping wound of his thigh, the result of the futile searching.

It is a deplorable fact that this modus operandi is still practiced, not only among the general practitioners, but even among surgical specialists.

79. By realizing that *fractures of the leg* constitute about 16 per cent. of all fractures and that they show a great tendency to displacement, the importance of the Roentgen rays as a controlling means during treatment becomes evident at once. Plate XIX shows an oblique fracture of the tibia on a boy of 10 years. The slight backward displacement of the lower tibial fragment caused a small gap at the anterior portion of the astragalo-tibial junction, which, to the uneducated eye, might appear as a subluxation of the astragalus. But the relations within the tarsal bones are entirely normal, the gap between the astragalus and calcaneum representing the infantile osseous state.

The presence and extent of *osteomyelitis*, so frequently found in the tibia, can be diagnosed by the rays, the focus always appearing well marked. The ease and security with which these operative procedures can be carried out under the control of the rays cannot be emphasized too much. Formerly it was

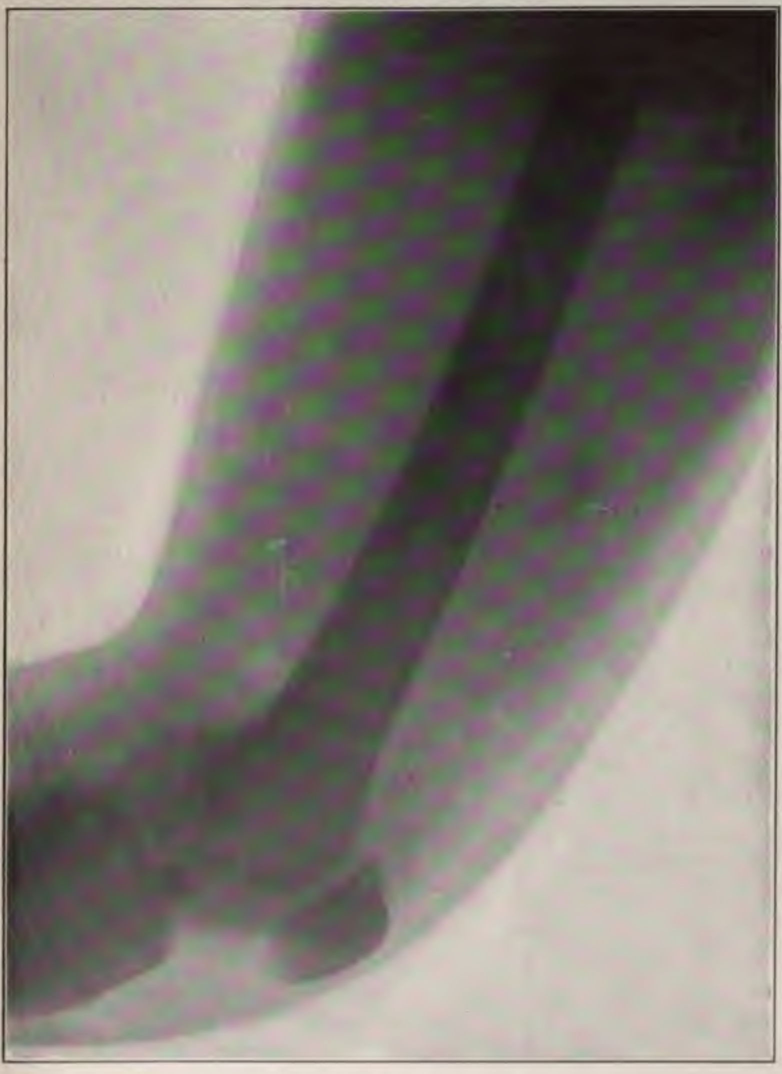

PLATE XVIII.

Bullet *in the Knee-Joint. The Shadow at the Middle of the Thigh Indicates the Entrance of the Bullet, (Attention is Called to the Normal Anatomic Relations of the Knee-Joint.)*

deemed advisable to chisel up the whole length of the bone in order to be sure that every possible focus was really reached. Now the skiagraph shows even the length of the incision that is necessary for a thorough removal. See Arts. **132** and **133.**

80. In *malunion*, osteotomy is simplified by the rays. The *arrest of growth* of the tibia after operations for necrosis can be well studied. *Rachitis* and *tuberculosis* also offer a wide field for study in this region.

Osseous cysts at the upper as well as the lower end of the tibial epiphysis are of not infrequent occurrence. They are confounded sometimes with osteosarcoma, a most unfortunate accident, indeed, since it frequently means unnecessary amputation.

From a skiagraphic study of a series of osteosarcomas to be spoken of in detail later (Art. **137**), one feels justified in saying that in osteosarcoma the outlines of the bone are always more or less abnormal and indefinite, some areas even appearing entirely translucent; while in osseous cysts the cortex appears thin and narrow, but well marked and regular. The fluid center of the bone is entirely translucent, the light shade showing the same regularity. The adjacent epiphyses are normal.

It is especially the regularity of the texture of the walls of the cavity, as they appear on the skiagraph, that seem to be the characteristic skiagraphic feature of osseous cysts in contradistinction to the irregular texture of osteosarcoma. As to further differentiation, it may be added that the vicinity of an epiphysis is also in favor of osseous cyst for obvious histological reasons.

In a case of osseous cyst of the tibia presented to the surgical section of the New York Academy of Medicine, March 11, 1901, the skiagraph revealed the presence of a large triangular shade, the base of which corresponded to the epiphysial line. The triangle was surrounded by a narrow, dark, and regularly arranged shade that represented the distended, but otherwise normal, cortex of the tibia. The light shade was interpreted as a cavity, presumably containing a fluid of some kind. The normal outlines of the fibula could be distinctly recognized through the light area, although the inner surface of the leg rested on the photographic plate.

The marked regularity of the texture of the cortex, as well as the uniformity of the light shade representing the cavity, showed that osteosarcoma was not present in this case, wherefore a conservative operation was advised, which was performed with a most gratifying result.

81. Ankle-Joint.—The ankle-joint and its vicinity are frequently the seat of injuries and diseases of various kinds. The history of the faulty diagnosis in this region would fill many volumes. Nowadays, differentiation between fracture, dislocation, distortion, contusion, and last, but not least, inflammatory processes, is easy. Plate XX shows a fracture of the external malleolus in a woman of 40 years. The fragment being displaced far backwards, it is evident that the relations in the arch of the ankle-joint were greatly disturbed. The skiagraph indicates how far the fragment has to be pushed forwards. The healing process, after operation for pes equino-varus and valgus, can be easily studied and influenced accordingly. Most cases of so-called distortion prove to be fractures pure and simple when looked at by means of the "Roentgen eye-glass." Sometimes very small splinters are represented which are severed from the bone surface. They are naturally imbedded in bloody effusion, which prevents their recognition by palpation, so that naturally the diagnosis "sprain" is made. Massage can seldom be borne by the patient, because the friction caused by this treatment presses the sharp bone splinters forcibly against the injured bone. The patient will, on the other hand, be comfortable if treated after the general principles of fracture treatment, i. e., immobilization.

If there are no little bone fragments, but only a hematoma from lacerated tissue, then, of course, massage is the treatment par excellence, and immobilization means unnecessary delay.

82. Fractures of the *astragalus* and *calcaneum* were often confounded with Pott's fracture, the final surgical result, naturally, being very unsatisfactory. Minute anatomical knowledge is necessary to appreciate a skiagraph of these bones thoroughly.

Plate XXI shows osteo-epiphysial separation of the calcaneum

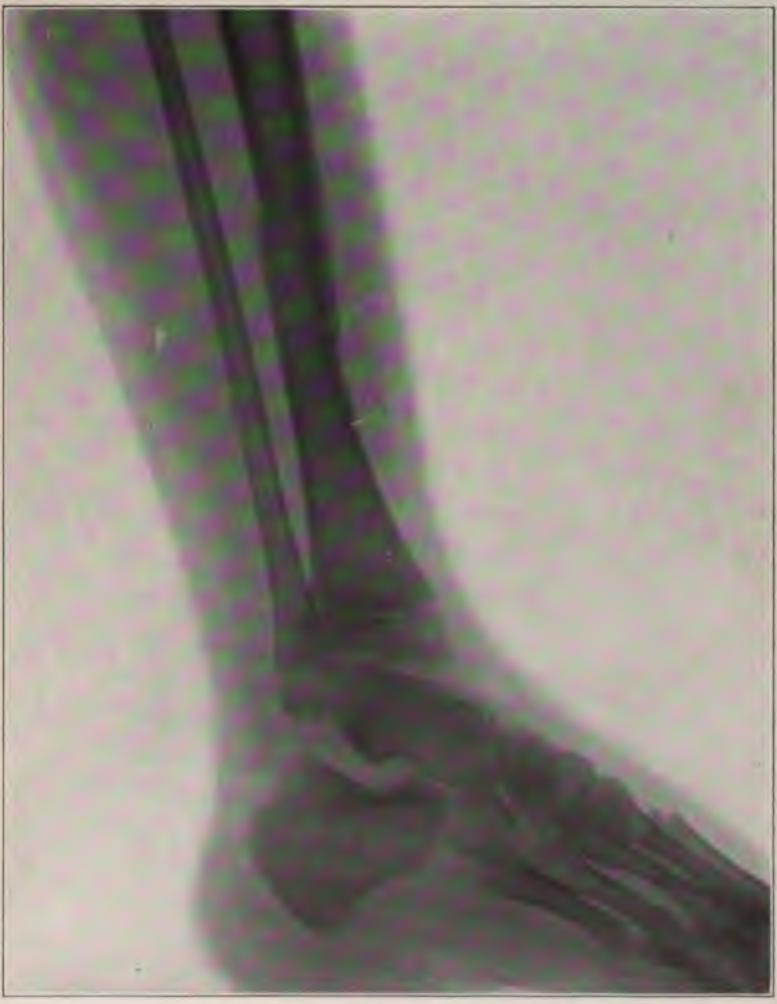

PLATE XIX.

Oblique Fracture of Tibia on Boy of 15 Years.

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in a girl of 17 years. Great functional disturbance of the foot being present, a bone-injury was thought of at once. The first exposure made while the planta pedis rested on the plate, revealed nothing abnormal. A second exposure, made while the internal malleolus rested on the plate, showed the true condition indistinctly. The third exposure, also made laterally while the external malleolus rested on the plate, brought it out very markedly. (See Art. 162 on False Interpretations.)

How misleading the lack of such knowledge may become is evident from the fact that the *os intermedium cruris* (os trigonum tarsi) has been mistaken for a fragment severed from the astragalus. This bone is a typical part of the tarsus of all mammalia, and its frequency is estimated at from 7 to 8 per cent. Shepherd, who mistook this bone for a fractured fragment, says: "The fact that this fracture is not mentioned in any of the textbooks of surgery or in special treatises on fractures would easily be accounted for by its only being discovered by dissection; it causes no deformity, and the symptoms it would cause during life would probably be obscure." The same author tried to produce this fracture, artificially, on the cadaver, but "in every case," he says, "where this maneuver was performed, I failed, even when the greatest force was used, to break off a little process of the bone mentioned above." Pfitzner regards the os trigonum tarsi as an integral part of the posterior process of the astragalus in the adult, which is analogous to the os intermedium antibrachii.

The practical significance of this resurrected bone is evident from the case of a laborer, age 40 years, who said that he broke his ankle by falling from a stairway. After 4 months' treatment in a mining district of Pennsylvania, he still complained of considerable pain in the ankle, the intensity of which increased when he stepped on the foot. Limping was also present to a great extent. The protuberance of the left external malleolus, and the well-marked tenderness of this region, pointed to the fracture of the external malleolus united in a deformed position. On the internal side but little swelling and considerable tenderness could be noted. A skiagraph taken in the anteroposterior direction with a slight lateral turn showed a dehiscence to the extent of ½ centimeter on the external malleolar side. The gap was partially filled with callus. On the internal malleolar side the marked evidence of a separation of a small bone fragment could be seen, just as it is observed in Pott's fracture. It appeared to be displaced downwards to the extent of ½ centimeter and its upper surface looked so much like the lower surface of the internal malleolus that it seemed to be almost certain that the two surfaces belonged to each other and had only recently been separated by external violence. Consequently, it was assumed that there was a typical case of Pott's fracture and that the pain in the sphere of the internal malleolus was due to the pressure caused by the displaced fragment. While considering its removal a second skiagraph in the lateral position was studied, in which the integrity of the internal malleolus was recognized. Now it became clear why there was no callus formation around the alleged bone fragment and why at the same time the connection with the astragalus was so close. By skiagraphing the healthy foot, a normal os trigonum tarsi was found. This showed that the patient had sustained a fibular fracture only, which became united in a deformed position, and that the alleged fragment, which had been so misleading at first exposure, represented the intact os trigonum tarsi. Plate XXI shows the presence of an os intermedium cruris.

83. The isolated fractures of the *other tarsal bones* were seldom recognized in a living person prior to the discovery of the Roentgen rays. As to the best location of the foot, it may be said that it is easily skiagraphed in the direction of the dorsum toward the planta pedis from the toes up to the upper third of the metatarsus. But further back the first and third cuneiform bones and the scaphoid offer an obstacle so that it is necessary, also, to skiagraph the foot on these portions transversely by having the outer surface rest on the plate. It is by this procedure only that the isolated shadows of the astragalus, the calcaneum, the os cuboideum, the scaphoid, and the fourth and fifth metatarsal bones can be distinctly outlined so that false interpretations can be excluded.

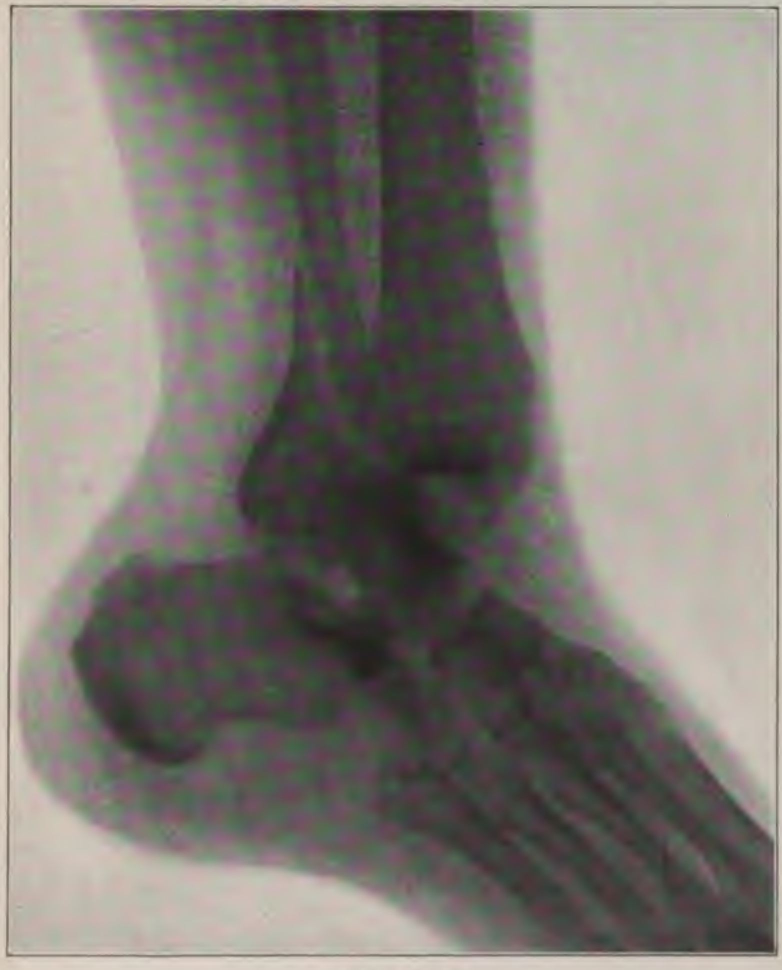

PLATE XX.

Fracture of External Malleolus in Woman of 40 Years.

84. How important the question of *projection* is, becomes evident when we consider that grave errors may sometimes occur even if all the preliminary conditions required for a thorough understanding of the case seem to be fulfilled.

A boy, age 4 years, while playing in the street, fell against an iron bar. Being unable to rise, he was picked up and carried to St. Mark's Hospital, where in the first instance moderate pain was noted beside the functional disturbance. There was neither any difference in level, nor any deformity, nor any shortening, nor the typical equinus position. A photograph taken 2 days after the injury only showed a very moderate and uniform swelling of the leg. Abnormal mobility and crepitation in accordance could be produced only by very rough manipulations.

On the day following the injury two skiagraphs were made in different positions, one of them in the dorsal and the other in the lateral position. The one that had been skiagraphed by direct irradiation, the center of the platinum disk of the tube being perpendicular to the anterior surface of the leg, did not show the slightest indication of a fracture, while the one that represented the leg irradiated from the outer aspect of the tibia showed a marked line. The fracture presented the oblique type in the middle of the tibia, the fracture line running from below anteriorly to above posteriorly, the upper tapering fragment overlapping the lower end. No sideward displacement having been present, it can be understood why the rays reaching the long axis of the tibia in a vertical direction did not show the fracture line. A very slight change in position, when the inclination toward the fibular direction amounted to less than 1 millimeter, brought out the fracture distinctly.

Now, if, as is the custom in general, a skiagraph had been taken in the anteroposterior direction only, and if the manipulations made during the first examination were carried out as gently as they properly should be, the fracture might have been overlooked entirely. And if, in view of the local pain and tenderness, the swelling, and the functional disturbance, the possibility of a fracture had been seriously considered, the skiagraph might have silenced the uneasy conscience. If the case had been brought before a jury, the expert might there, on the strength of the first skiagraph, have testified in good faith that there was no fracture. This experience again teaches the necessity of adopting the principle of always taking at least two skigraphs in two different positions in all cases of suspected fracture.

Lately, however, with our improved tubes, we are able to represent the fracture line even in most cases of overlapping. *Foreign bodies* in the foot are often overlooked and a series of false conjectures is sometimes built on the ignorance of their presence. Plate XXII illustrates the case of a dwarf of 24 years, who was a round-trip patient in numerous clinics of New York City. He had a slight swelling on the outer aspect of his foot which was diagnosticated as periostitis, ostitis, osteoma, osteosarcoma, beginning tuberculosis, rheumatism, arthritis, syphilitic proliferation, badly united fracture, etc. Later on, amputation and exploratory incision had been advised. After having suffered for 2 years he was ready to submit to anything which would relieve him from the pain he experienced while walking. The Roentgen rays cleared up the situation at once. Now he remembered, that 2 years before, while sleeping on a lounge, he fell on the carpeted floor and noticed a sharp pain in his foot which he explained by the fall itself. The Roentgen rays showed that he had fallen on a needle sticking out of the floor; removing the needle, we are proud to say, cured his rheumatism, etc. at once.

FRACTURES OF THE METATARSUS.

85. It is generally accepted that the superficial location of the *metatarsal bones* makes the recognition of their fractures easy. Still, while this may be true of the first and fifth metatarsi, on account of their accessibility, the dense tendinous and ligamentous tissues overlaying the second, third, and fourth metatarsi are apt to veil the fracture-signs within their tract. The difficulty of differentiation is much greater, when, as is the rule, the fracture is associated with the injuries of the soft tissues which cause edema and swelling.

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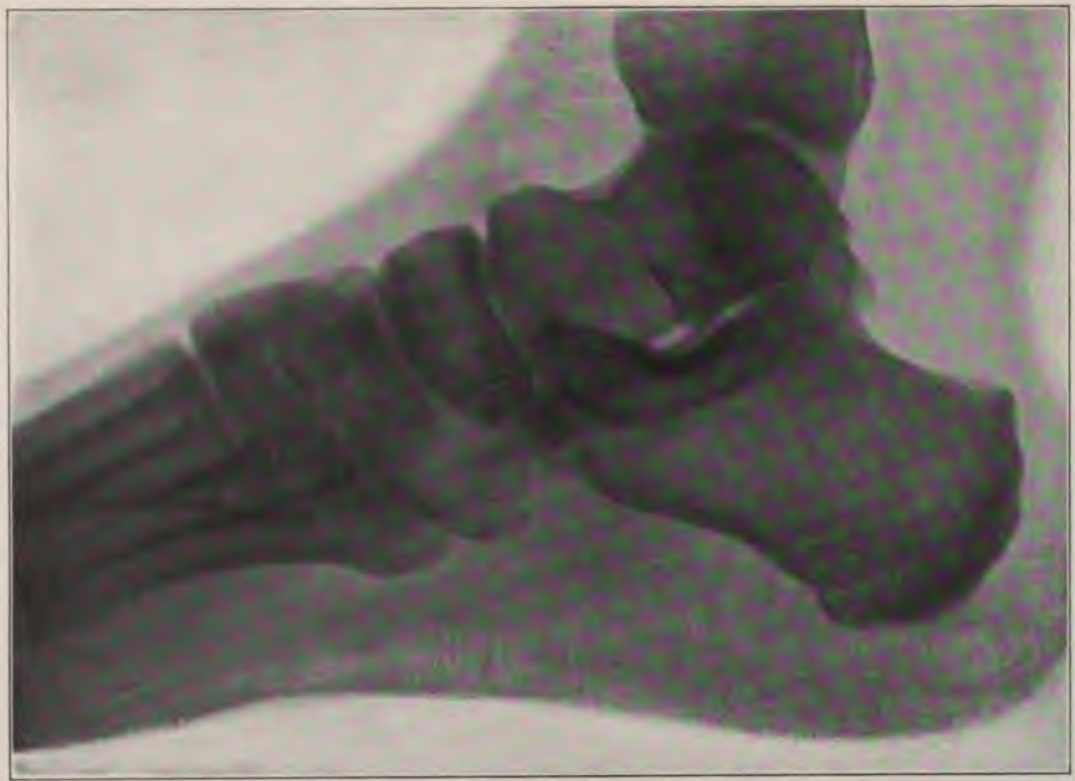

PLATE XXI.

Osteoepiphysial Separation of Calcaneum. (Attention is Called to the Presence of the Os Intermedium Cruris in this Case.)

How often metatarsal fracture has been overlooked can be estimated by the fact that, before the discovery of the Roentgen rays, most cases of fracture of the second or third metatarsus were taken for a pathological change in the soft tissues—in the German army known as "foot edema." It was reserved for the Roentgen rays to disclose that this much dreaded condition was a fracture pure and simple, and that it was produced by overburdening the marching soldier.

The textbooks treat metatarsal fracture as a stepchild, most of them saying that it would require neither detailed description nor any special mode of treatment. A few say that if there would be any displacement it would be toward the dorsum of the foot. Only Hoffa alludes to the possibility of plantar displacement also. But nowhere is reference made to the lateral displacement, which we regard as of no infrequent occurrence and also as an important complication, since it is always followed by considerable functional disturbance. The fact that the lateral displacement was never recognized before explains fully why efforts of reduction have neither been made nor advised; consequently, the fragments, left to themselves, whether in a general immobilizing dressing or not, unite in a deformed position, and bony enlargements, as well as functional disturbances, have been the result. The edematous feet of persons who must work hard, or must march, or stand on their feet during the whole day, furnish a striking illustration of the consequences of badly united metatarsal fractures, as they are disclosed at the present time by the Roentgen rays. It is obvious that the more accurate and various diagnosis that these rays enable us to make must also inspire different plans of treatment. Previous experiments have shown that metacarpal fragments are invariably held in place by elastic pressure. The same principles obviously apply to metatarsal fracture.

For the fracture of a displaced metatarsal bone, two rubber drainage tubes of moderate size are chosen and lightly pressed into the adjoining interosseous spaces at the dorsum so that they fill them to a certain extent. If two metatarsi are fractured, three drainage tubes are necessary, and so on. The tubes are kept in situ by strips of adhesive plaster; thus the recurrence of the displacement is absolutely prevented. The dorsum is then surrounded by a moss-splint, a material that after being dipped in cold water adapts itself to the contours of the foot like a cast. The whole is protected by a plaster-of-Paris dressing that reaches from the toes to the lower third of the leg. The patient remains in bed for about 10 days. Then an ambulatory dressing is applied after the principles elucidated above.

When skiagraphed through the plaster-of-Paris dressing, the formerly displaced fragments should be found in exact apposition. If not, the dressing must be reapplied in the correct position. There is no doubt that in pursuing these therapeutic principles, which are based on a correct anatomic diagnosis, alleged metatarsalgia and similar ailments will become a very rare affection.

Plate XXIII represents the case of a man of 31 years who sustained a fracture of the lower epiphysial ends of the third and fourth and a fissure of the second metatarsus. While smoothing the asphalt pavement on the street, holding in his hand a bar that weighed 40 pounds, he was knocked down by a street engine coming behind, falling forwards. While the second metatarsus shows only a slight sideward bending, the dentate fragment of the third metatarsus is markedly displaced outwardly. The lower fragment of the fourth metatarsus is not only displaced, but its external portion is also tightly pressed against the fifth metatarsophalangeal joint. The patient was able to walk in 1 week in an ambulatory dressing and made an uneventful recovery.

86. The *sesamoid* below the head of the first metatarsus sometimes is fractured by direct violence, a fact that was also never before recognized. The various osseous changes of the foot in *acromegaly* are an interesting subject for skiagraphic study. The phalanges appear broader and thicker than normal and show no osteophytes. The metatarsi also show massive structures.

87. The pathological anatomy of *hallux valgus*, as well as that of *arthritis of the large toe*, is also much better appreciated

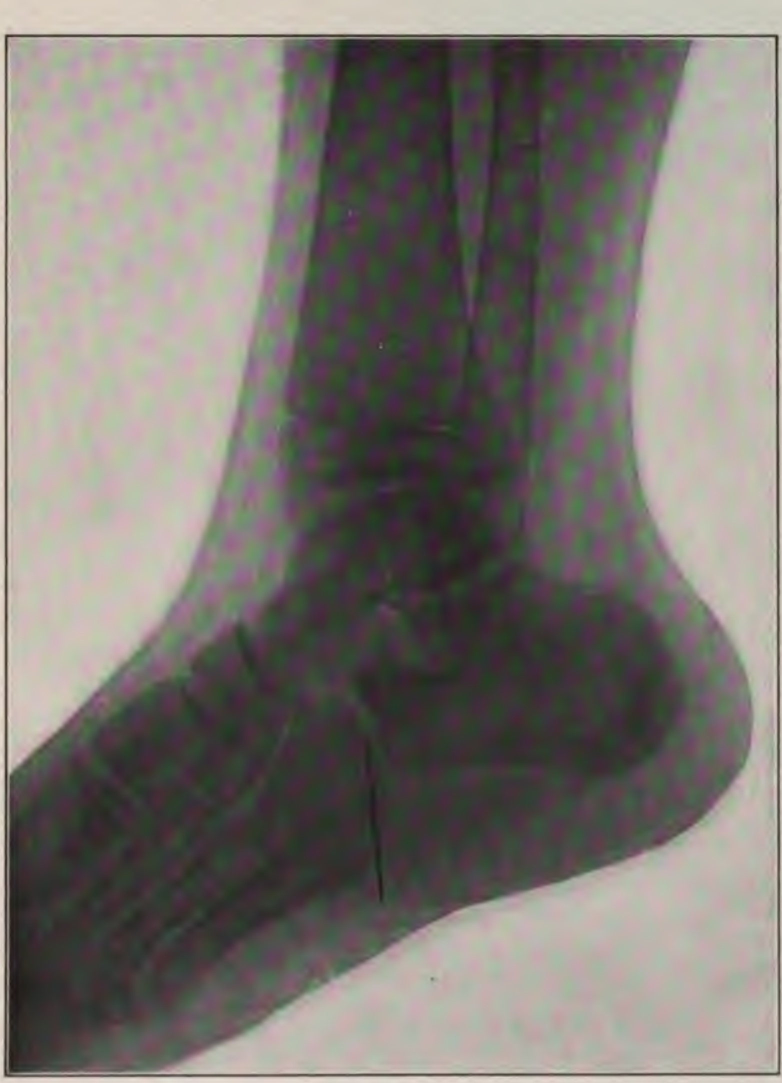

PLATE XXII.

Needle in the Tarsus. (Note the Non-ossified Epiphysial Lines in this Case of a Dwarf of 24 Years.)

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and judged since the advent of the rays. The toes need frequent skiagraphic representation on account of the entrance of foreign bodies, especially of needles and tacks.

Malformations, like syndactylism, etc., can also be well studied. The exact anatomic diagnosis that we are able to make now enables us to determine whether surgical interference is possible, and if so, it outlines clearly our modus operandi beforehand.

88. To avoid false interpretations of skiagraphs of children, it should be remembered that the lower epiphysis of the tibia and the fibula show their osseous nuclei in the first and second years, and unite with the diaphysis between the eighteenth and the twenty-fifth year—according to the skiagraphs, as early as before the eighteenth year. The osseous nucleus of the astragalus and the calcaneum appears *intra utero*, that of the *cuboid* shortly before or after the birth, that of the cuneïformia between the first and the fifth year, and that of the *os naviculare* from the first to the fifth year. The osseous nuclei of the *metatarsal* bones and of the *phalanges* appear from the second to the tenth year, and unite with the diaphysis between the sixteenth and the twenty-second year.

SHOULDER AND UPPER EXTREMITY.

89. The shoulder can be skiagraphed in the sitting, dorsal, abdominal, and lateral positions. It is fluoroscoped best while the patient is in the sitting posture. Irradiation takes place best in the perpendicular direction, the tube being as near as possible and the glenoid cavity being regarded as the center. An abdominal exposure is necessary as a rule. Children require between 3 and 4, thin adults about 6, and stout adults 7 to 8 minutes exposure.

A good skiagraph of the shoulder-joint is best obtained from the anterior aspect, in other words, in the abdominal position. The sigmoid form of the *clavicle* must appear well marked. The *scapula* is best studied posteriorly, that is, in the dorsal position. Its triangular shade can be well differentiated from the ribs. Its spine can be followed in its course, running parallel to the clavicle and ending at the acromion. The acromioclavicular junction shows a hiatus, which, in the early days of skiagraphy, was mistaken for a diastasis of the joint. An increased knowledge has taught that this apparent diastasis is by no means pathological and that there is a normal gap between the osseous ends of the acromion and the acromial end of the clavicle (see Plate XXIV). The glenoid cavity, containing the head of the humerus and the major and minor tubercula, should also be well marked. Between the clavicle and the scapular spine appears the dark shade of the coracoid process.

90. Tumors of the clavicle can be differentiated by skiagraphy. Atrophy of the clavicle in aortic aneurism can be represented. The true character of pulsating tumors, erroneously taken for subclavian aneurism, may also be shown. Tubercular foci are also sometimes found in the clavicle. It is needless to say that dislocation of the clavicle is easily differentiated from fractures by the aid of the rays.

Skiagraphy of the scapula is indicated in tumors, especially in osteosarcoma. How important the rays are in various injuries of the scapula, especially in fractures, may be illustrated by Plate XXV, which represents a fracture of the neck of the scapula that had been taken for a fracture of the anatomic neck of the humerus by several physicians before the skiagraph was taken. The deformity was corrected, and it is needless to emphasize that without this correction the patient would have been a cripple. Fracture of the ribs was also present in this case.

91. The *shoulder-joint* was formerly regarded as a regular crux medicorum. While dislocation, for instance, should be easily differentiated by the possibility of palpating the joint-surface of the shoulder, there are, in fact, many unrecognized cases. Plate XXIV shows a case of subglenoid dislocation of the shoulder in a man of 37 years. The empty joint-surface presents itself clearly.

Plate XXVI shows a deformed union after fracture of the surgical neck in a girl of 15 years who fell from a window in the fourth story. The force of the fall fortunately was broken by wash lines strung below, so that the patient escaped with an

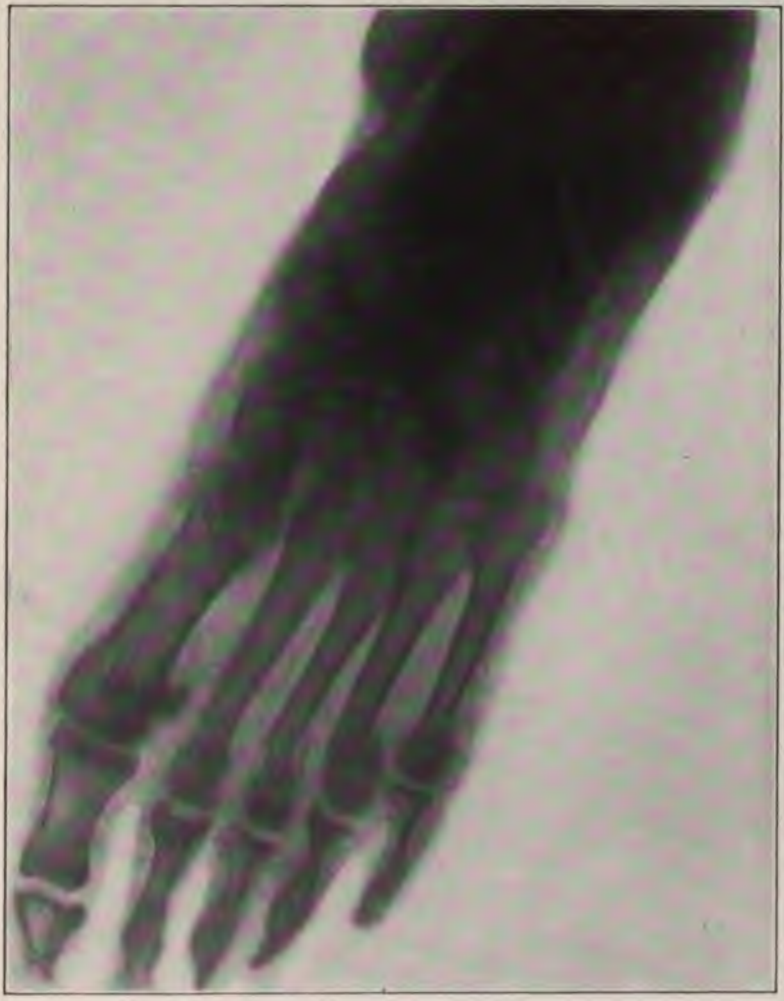

PLATE XXIII.

Metatarsal Fracture. Fracture of the Distal Epiphysial Ends of the Third and Fourth and Fissure of the Second Metatarsus in a Man of 31 Years.

extensive contusion of the right foot, a wound the length of 6 inches at the frontal region, and a fracture of the surgical neck of the right humerus. The competent family physician reduced the fragments at once, but they slipped out again; 5 weeks afterwards we noted a pronounced protrusion of the lower fragment, which was united to the small upper fragment in juxtaposition. We were astonished to find that in spite of the immense deformity there was hardly any functional disturbance at the time. Osteoclasïs, however, was performed, which, while not restoring the fragments to a blameless position, brought about considerable improvement.

This again shows that the significance of a skiagraph for the purpose of estimating the degree of functional disability is not always conclusive. (See Art. **164.**)

While fractures of the shaft of the humerus are usually too well recognized without the aid of the rays, there are some details that cannot be ascertained without them. Plate XXVII shows a green-stick fracture in a lad of 9 years. The skiagraph showed that the axis of the humerus was bent and this knowledge enabled us to redress the fragments into their proper direction 3 weeks after the injury; still, who has never been guilty of confounding some of its various injuries? Aside from differentiation between pre- and subglenoid dislocation and fracture of the anatomic neck of the humerus, there remains the various inflammatory processes—traumatic, rheumatic, arthritic, syphilitic, and tubercular—and the tumors, like enchondroma, osteoma, and osteosarcoma. Osteosarcoma can be recognized at an early stage. It should be borne in mind that most cases of osteosarcoma give a history of an injury, so that the swelling is sometimes erroneously taken for callus-proliferation. (See Art. **137.**)

92. Just as in intra- and extrascapular fracture of the head of the femur, the Roentgen rays show that in fracture of the head of the humerus, schematic distinction between fracture of the anatomic and surgical neck, as well as transtubercular fracture, cannot always be made. In the case of a woman of 56 years this was illustrated in a very striking manner.

The patient had fallen about 5 weeks before, striking the right elbow on the pavement. There had been ecchymosis at the elbow at the time, suggesting a fracture there, but no fracture had been found at this point. When examined 4 days later there had been absolutely no objective symptoms of fracture except a slightly abnormal mobility in the region of the head of the humerus. The pain here was intense. There was, however, no swelling or deformity. The skiagraph showed a fissure line running downwards and inwards from the tubercles to about the surgical neck of the humerus. Another skiagraph taken 2 weeks later, and viewing the bone from the back, showed a line that might lead one to look upon the case as one of fracture of the anatomical neck. The second skiagraph showed chips of bone—a condition that, as mentioned before, is not infrequently met with in other cases supposed to be only examples of contusion. When such chips of bone can be recognized, the massage treatment for sprains is manifestly inappropriate.

To avoid erroneous interpretations, the fact must also not be lost sight of that the union between the epiphysis and the diaphysis of the head of the humerus is not perfect before the twentieth year.

93. Sometimes the shaft of the humerus is the seat of a *periostitic* process or an *osteomyelitic focus*. In such cases a preceding trauma is often reported. The pain, the edema, the fever, and the general debility may be sometimes so little marked that differentiation becomes difficult. The skiagraph not only clears this difficulty of diagnosticating this disease, the true etiology of which is still so obscure, but also furnishes a trustworthy guide for the operative technic at the same time. (See Arts. **131** and **132.**)

In the case of a woman, age 20 years, the slow onset of the symptoms did not seem to be in favor of an acute inflammatory process. Pain being present only temporarily, the fear of a malignant growth was apparently not unjustified. The skiagraph at once did away with all anxiety, since it revealed the presence of a circumscribed osteomyelitic focus at the middle

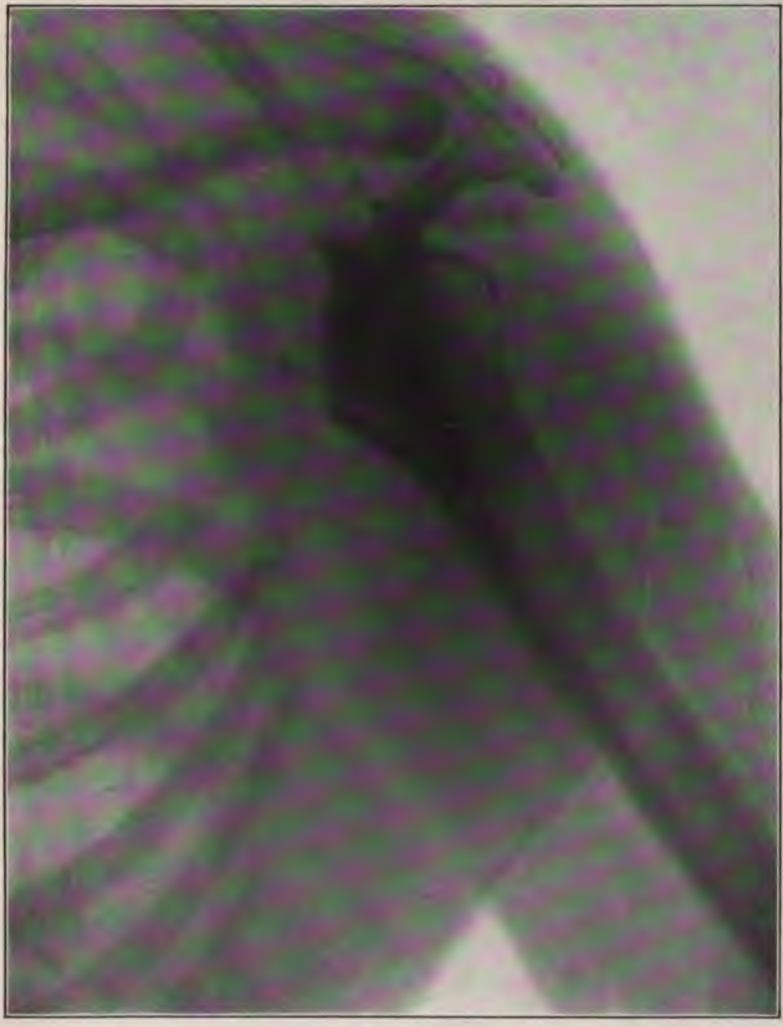

PLATE XXIV.

Subglenoid Dislocation.

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of the humerus. The focus was easily exposed by the chisel under the mentorship of the skiagraph. That the skiagraph has also spoken the truth by demonstrating the integrity of the remaining portions of the humerus was shown by the speedy recovery.

Plate XXVIII illustrates the case of a man of 28 years who was shot 3 years before the skiagraph was taken and who since had suffered from the symptoms of pressures on the median nerve. Two exposures were made, one on the flexor arm, another on the extensor side. In proportion to an angle of 90°, 4 metallic letters were attached on equal intervals to the surface of the upper arm by adhesive plaster, *A* illustrating the anterior, *P* the posterior, *I* the interior, and *E* the exterior aspect, as shown by the skiagraph. The point of recognizable attachment was made at the integument before by marking them with nitrate of silver. The comparison of the various diameters revealed the location of the bullet, which was extracted under local anesthesia. The bullet, on account of having struck the bone, had assumed a flattened shape.

94. Elbow-Joint.—The elbow-joint, the knee of the upper extremity, has also been a frequent source of grief to the busy practitioner. The general principles of diagnosis and therapy, Arts. **76** and **77**, in regard to the knee-joint also hold good for the elbow. Although the textbooks describe a series of well-pronounced signs characteristic for the various types of injuries of the elbow, clinical experience shows that even the apparently simplest disorders are often misunderstood. Plate XXIX illustrates the case of a woman who sustained a backward dislocation of the elbow by falling from her wheel. The diagnosis of a reputable surgeon was fracture of the lower end of the humerus. When, after 4 weeks' treatment, the swollen elbow still appeared much deformed, the patient insisted that something was wrong. Under the guidance of the skiagraph the deformity could still be corrected.

In such cases it is the duty of every physician to explain to the patient why, in view of the extensive swelling, such an error could easily be made without the aid of the Roentgen rays, and thus exonerate his colleague, not forgetting the old story about the motes and beams. At the same time, a physician of common sense should regard such an experience as a good lesson for the future; this misfortune will then turn out to be a lucky incident for him in the end. On the other hand, on account of the backward position of the lower fragment in a fracture of the lower end of the humerus, backward dislocation may erroneously be thought of, as it happened in the case of a girl of 12 years illustrated by Plate XXX. Crepitus being absent on account of impaction, it was not until the rays were consulted that the diagnosis osteoepiphysial separation could be made.

Another typical case is the following: A laborer who had been injured by a machine shows a fracture of the middle of the humerus and at the lower third of the ulna. The patient was treated by a good physician, but no skiagraph was taken at the time. The treatment of the humerus was excellent, the fragments having been held in exact apposition, as is shown by the very slight evidence of the line of fracture. The ulna fracture had not been well reduced, but it could not be seen that the deformity of that bone interfered seriously with the function of the arm. But in the elbow-joint there was a very important lesion that had not been detected by the physician, although it was under his care for 2 years. The man's arm eventually became paralyzed, and it was thought there might be some callus proliferation in the humerus, and for that reason it was decided to cut down upon it and free the nerve. But the condition remained unchanged. If at that time, 1½ years after the injury, resort to skiagraphic examination had been made, the surgeon would not have cut down upon the nerve, because the picture would have shown no displacement. This fact would have excluded the possibility of compression of the nerve. If there was compression of the nerve he would have known that it must be somewhere else. When we saw the patient for the first time a skiagraph in the flexed position was taken, which pointed to dislocation of the radius. It did not appear very marked, and so an uneducated eye might, on a superficial examination, have overlooked it. This also emphasizes the importance of taking two different pictures, for, in the second

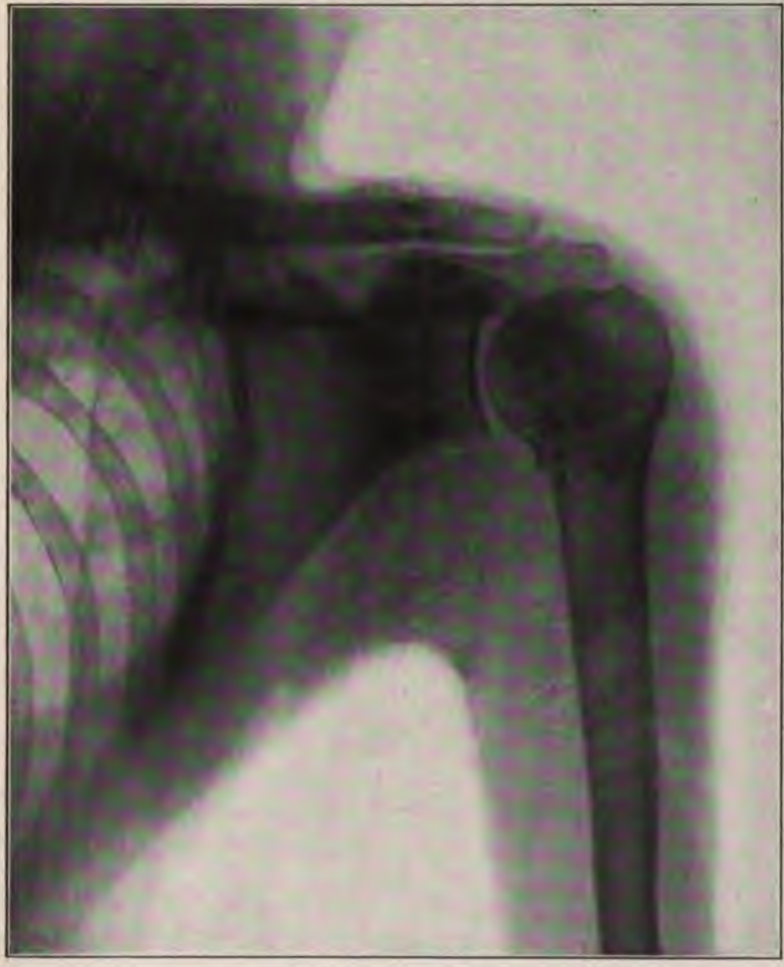

PLATE XXV.

Fracture of Neck of Scapula.

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one, taken in the extended position, it is made absolutely evident even to the unskilled eye. After 2 years the patient suggested to the physician that a skiagraph be taken. The latter replied that this was interesting and could be done. So he sent the patient to a "Roentgen ray photographer" and wrote him that the humerus should be skiagraphed. Apparently he did not attach any importance to the injury to the elbow. But the patient did not like the idea of consulting a mechanic and preferred the opinion of a surgeon. The true state of affairs was of course concealed and the patient simply advised to submit to another operation to relieve the nerve further downwards. Now, if a skiagraph had been taken 2 years before, the physician would have seen that the humerus was in perfect position and that the ulna showed displacement, which would have easily been converted then by slight inward pressure. He would also have discovered the radial dislocation and could have easily reduced it at that time. The patient is still paralyzed, and it is very questionable if he will recover.

95. If there is a multiple condylic fracture, a perfect restitutio ad integrum cannot be expected. The skiagraph furnishes the documentary defense for the physician who attended first. On the strength of a skiagraph showing the constellation of splinters in the elbow-joint the ankylotic elbow can always be justified. Plate XXXI shows a multiple fracture of the lower third of the humerus in a woman of 27 years, 9 months after the injury. The skiagraph indicates that the fracture was of such a serious nature that a good result could not have been expected under any circumstances, splinters of bone being scattered and imbedded in the soft tissues. If the skiagraph had been taken at the outset the surgeon would have been placed in a position to say positively that it was utterly impossible to get a good result. Thus he would have had a document to prove the serious nature of the injury, which was caused by an extreme degree of violence. Only a fool would, on the strength of the picture, have expected him to restore to its normal condition the lower end of the humerus, which was almost completely shattered.

On the other hand, the Roentgen rays enable the surgeon to correct the position of one or another fragment, and by frequent changes of the immobilizing dressing, repeated corrections can be made. The skiagraph invariably shows the relations of the fragments, even through a plaster-of-Paris dressing. Thus the surgeon always knows if his attempted reposition is correct.

96. The *median* as well as the *radial* nerve may become lacerated by the splintering of the bones. This requires immediate neurorhaphy. Of course, the nerve fragments cannot be represented by the rays, but the location and the character of the fracture, in conjunction with the symptoms in the sphere of these nerves, make the diagnosis positive and dictate the operative steps.

97. In children the skiagraphic anatomy of the elbow-joint may be falsely interpreted. It should be remembered that the osseous nucleus of the interior of the capitulum humeri appears between the second and third years. Another nucleus shows in the internal epicondyle at the fifth year, a third in the trochlea between the eleventh and twelfth years, and soon afterwards a fourth in the internal epicondyle. The nucleus of the internal epicondyle unites with the diaphysis between the sixteenth and the twentieth year; but the other three nuclei form a synosteosis among themselves at the seventeenth year, then constructing the uniform osseous epiphysis which completes its synosteosis with the diaphysis at about the twentieth year.

In very young children the eminentia capitata appears as if entirely severed from the humerus, although the relations are normal. The explanation of this important phenomenon is that the epiphysial tissues are not sufficiently ossified to produce a shadow on the plate. If these points are not thoroughly considered a displaced fracture fragment might be erroneously diagnosticated. The lower epiphysis of the humerus consists of four nuclei, which do not ossify until from the eighth to the seventeenth year. The epiphysis of the *trochlea* as well as of the *olecranon* do not ossify until between the seventh and the twelfth year, which explains why an osseous nucleus is still connected with its neighboring epiphysial nuclei and the diaphysis, connected by cartilaginous tissue, appears as an isolated piece of bone which might erroneously be taken for a fragment.

It must also be borne in mind that in fractures in childhood the process of ossification is influenced by various affections of the bone, like rachitis, for instance.

98. As stated before, inflammatory processes in the elbow-joint are to be viewed from the same points as those of the knee-joint. (See Plate XXXIX and Arts. **76** and **77.**)

99. **Fractures of the Olecranon.**—Fractures of the olecranon are found more frequently now than before the discovery of the rays. Experience furthermore contradicts the wide-spread opinion that the fracture of the olecranon does not happen before the fifteenth year. It is observed from the tenth year, when the nucleus for ossification appears. In a case of wide diastasis of the fragments, wiring is necessary. While union is taking place frequent fluoroscopic examinations should be made.

100. **Fractures of the Coronoid Process of the Ulna.**—It was thought that fractures of the coronoid process of the ulna were of rare occurrence. But, as in many other instances, experience with the Roentgen rays has taught that this type of fracture is much more frequent than was formerly believed. The fact that only recently we observed this type in three of our patients during the short space of 4 weeks seems to strongly support this assumption. By realizing that the normal coronoid process cannot be palpated through the thick muscular strata that protect it, the difficulty of making out the broken fragments becomes apparent. The strong lateral ligaments, as well as the annular ligament, which is strengthened by the brachialis muscle, form so strong a protection to the process that a displacement of its fractured fragment seldom takes place. This usual absence of displacement also explains why crepitus is ordinarily not produced. The presence of ecchymosis, as well as of an intense circumscribed pain in the cubital fold produced by strong flexion, are suspicious signs.

The latter would indicate that the process is pushed into the fossa anterior. It should not, however, be forgotten that this valuable symptom is entirely of a subjective nature.

Thus, a positive diagnosis can but seldom be made without using the Roentgen rays. The diagnosis will also determine the prognosis. If there is but little tendency to displacement the prognosis is favorable even when the diagnosis has not been made. But if there is any marked displacement the function of the elbow is greatly disturbed. In such an event, of course, the diagnosis is so much easier the greater that the displacement is. Nowadays this much dreaded condition need not be feared, since reposition of the fragments has become greatly simplified under the guidance of the rays.

The after-treatment is best conducted in a rectangular dressing of plaster-of-Paris. In the cases referred to the fragments were invariably found in a displaced position so that they projected into the joint, interfering with free motion. The projecting bone mass therefore had to be chiseled off.

In the case of a girl of 14 years, fracture of the lower end of the humerus and of the coronoid process of the ulna had occurred. Radial paralysis and acute muscular contraction followed to such an extent that the arm became perfectly useless. Under the guidance of the rays the protruding coronoid fragment was removed and the compressed nerve relieved. Whether after an elapse of 6 years since the injury this deplorable condition will still be remedied, has not been ascertained, the patient still being under treatment.

101. Fracture of the Diaphysis of the Ulna.—Fracture of the diaphysis ot the ulna is known to have a great tendency to displacement. If pressed against the radius, synosteosis may take place, thus rendering pronation and supination impossible. For correction, compare the principles emphasized in Art. 106 on the fracture of the shaft of the radius.

102. Fissure of the capitulum ulnæ is found in connection with the fracture of the carpal epiphysis of the radius. (See Art. 109.)

In *simultaneous fracture of the ulna and radius,* malunion is

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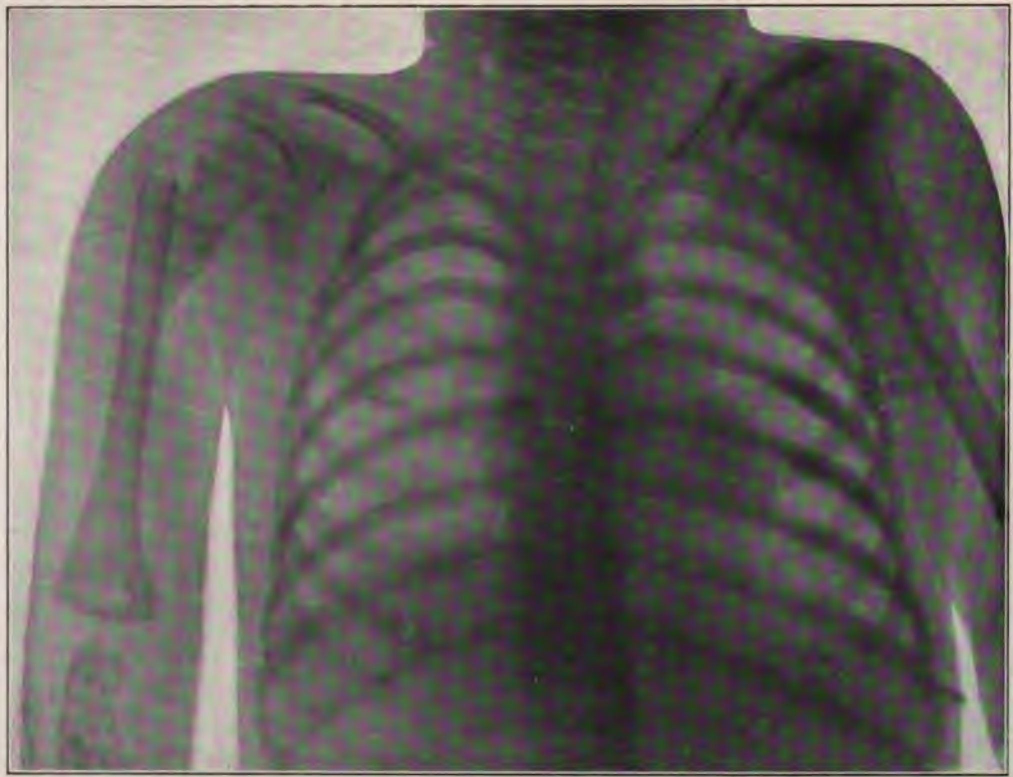

PLATE XXVI.

Deformed Union After Fracture of the Surgical Neck of the Humerus. (Note the Normal Relations of the Normal Shoulder and of the Thorax).

often observed. Plate XXXII shows deformed of radius and ulna in a laborer of 35 years. The fragments overlapped and became adherent by fibrous tissue in juxtaposition. Osteoclasis being impossible, severing of the fragments had to be accomplished by the chisel. In the case of a man of 39 years, who suffered fracture of both forearms by extreme violence, union failed to take place after 5 months. Skiagraphy revealed overlapping of the four bones. Both forearms showed false motion and their function was destroyed. Osteoplasty was performed under the guidance of the skiagraph.

The right forearm permitted of perfect reduction so that the fragments, after being refreshed, could be united by silver-wire. The bones of the left arm could not be pulled into proper position, wherefore they had to be shortened. A segment was cut out from one end and an acute triangle from the other in each bone, so that they could be rejoined without the use of silver-wire. A plaster-of-Paris dressing was then applied, through which skiagraphic examination showed the fragments in good apposition. The result was a perfect cure.

THE RADIUS.

103. The radius gives the surgeon more trouble than any other bone of the human skeleton. If it is only realized that fracture of its lower epiphysis is the most frequent fracture type —at least 18 per cent. of all fractures—its importance becomes evident at once.

104. Fractures of the Radial Head.—Isolated fracture of the head of the radius was regarded as being very rare. If the fragment is entirely severed, it will be recognized by palpation as a separate piece of bone. In addition it will not share the motions of the arm while alternately turned in pronation and supination, and in that case crepitus is seldom absent. Intense pain may point to the seat of the fracture, and sometimes it may be guessed by simple inspection, the biceps drawing the shaft forwards and causing a slight projection. But whenever there is an entire absence of displacement, contusion, or distortion, this error is apt to be made, particularly so when the swelling following the injury veils the symptoms, abnormal mobility especially not being noticeable. In former years it was only under anesthesia that such cases were once in a while diagnosed.

105. Fissures of the Radial Head.—It is evident that the diagnosis of the fissure of the radial head is still more difficult. It would seem that until the discovery of the rays its presence could never be clearly ascertained, and there can be no doubt that with our increasing knowledge and experience this fissure, also, will be recognized more frequently.

The following case will serve as an illustration. A woman, aged 24 years, in falling down stairs struck her right elbow against a piece of iron projecting from the stairway. She consulted a physician at once, who found the elbow much swollen and painful. No signs of a fracture were then detected.

Two days later the arm was in a right-angled flection and the region of the elbow-joint showed considerable swelling and tenderness equally distributed. The area above the radial head showed the presence of ecchymosis.

A skiagraph was taken at once in supination, the patient lying on her back. It revealed the presence of a fissure of the radial head beyond any doubt. There were, in fact, two distinct fissure lines, one running through the circumferentia articularis along its margin, and the other creating a trigonal segment, the base of which was formed by the internal margin of the circumferentia articularis and the tip by a splinter detached from the radial neck.

The treatment consisted in the application of a plaster-of-Paris dressing in rectangular flection, the forearm being kept in semipronation. A second skiagraph, taken 4 weeks later, showed ideal union, the external portion of the circumferentia articularis only protruding farther than it should normally. It also proved how quickly the evidence of the presence of a fissure becomes lost if there be perfect approximation, a circumstance to be borne well in mind from a medicolegal standpoint.

The function of the forearm did not become perfect until 3 months after the injury, the joint showing considerable stiffness at first, which yielded gradually to massage treatment. (See Annals of Surgery, March, 1901.)

Fissure of the radial head being of a decidedly intra-articular character, an effusion in the joint is a natural sequence, which explains the uniform swelling at the beginning as well as the stiffness at a later period. From the observation of this skiagraphic case we may learn that wherever observation shows no tendency to displacement it will be advisable to begin motion at an early stage, say after 10 days, in fissure as well as in fracture of the radial head. In relying on the skiagraphic mentor, our results will be far superior to those of the past. Even in the much-feared cases of fracture of the radial head, where the fragment is considerably displaced, a great deal can be done, or rather prevented, under the guidance of the rays.

The case of a man, age 32 years, gave an opportunity to diagnosticate a fracture of the radial head before the use of the Roentgen rays. This was easy because the much displaced fragment was freely movable. It had seemed that the fragments had been successfully reduced, but a skiagraph taken 12 hours after the injury, through a plaster-of-Paris wire splint, showed that the reposition was not perfect. Anesthesia enabled the displacement to be corrected perfectly in the half-extended position with satisfactory results.

Immobilization should be kept up for weeks in such cases, for premature contraction of the biceps muscle might separate the replaced fragment. If the fragments are not properly retained in place, the production of extensive adhesions might demand resection of the radial head. The same operation might be indicated if small fragments separated from the cartilage remained detached and act like foreign bodies so as to disturb the function of the elbow. The Roentgen rays enable us, in the event of this rare necessity, to trace out definitely the mode of such operations beforehand.

106. Fractures of the Shaft of the Radius.—Fracture of the shaft of the radius has a well-known tendency to displacement. Plate XXXIII illustrates a case in which the upper radial fragment was pressed against the ulna. Repo made by bending the forearm in the same manner stick is crossed over the knee, the ulna resting on of a table.

When it was thought that reposition was perfect of Paris dressing was applied. But the skiagraph, once, showed that reposition was imperfect, wh second effort was made, which proved to be succe such cases it is advisable to flex the opposite bone as possible, that is, in isolated radial fracture bend the and in isolated ulnar fracture bend the radius.

107. **Fracture of the Carpal End of the Radiu**

Fracture of the carpal end of the radius (erroneously calle Colles' fracture) is the most frequent fracture type, and is supposed to form at least 18 per cent. of all fractures. We think that it forms 22 per cent.

In no type of fracture have the Roentgen rays disclosed so many errors as in this much-disputed one. In most cases skiagraphy has revealed conditions that were not expected and that have required the original diagnosis to be more or less modified.

It has been found that the anatomic aspects of the various forms of fracture of the lower end of the radius differ more than those of any other fracture, and it is self-evident that such variants are by no means of indifferent importance in respect to treatment.

108. Since March, 1896, when we first began to skiagraph all cases of fracture and suspected fracture that came under our care, we have observed fracture of the lower end of the radius 123 times. In a number of cases fissure of the ulna coexists. Other surprising features are that simultaneous fracture of the styloid process of the ulna and of the scaphoid bone have been found in a great number of cases, complications that were formerly supposed to be of extremely rare occurrence.

Having regard to experience as well as to the information gained by the Roentgen rays, we have tried to classify those

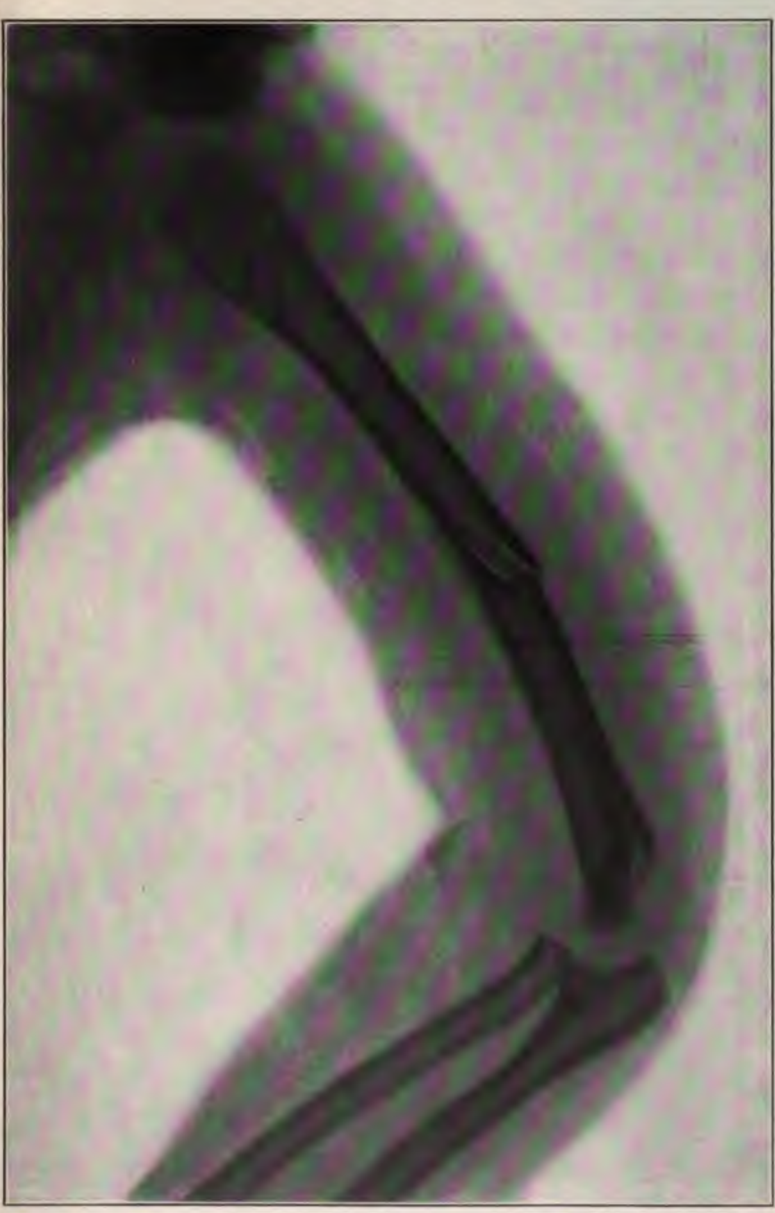

PLATE XXVII.

Green-Stick Fracture in the Middle of the Humerus.

forms of this much-disputed fracture that appear to be most characteristic, and must, accordingly, demand different therapeutic measures, viz.:

1. Epiphysial (chondro-epiphysial and osteoepiphysial) separation.
2. Fissure (fracture without displacement).
3. Complete fracture (simple and more or less displaced and multiple **T**- and **Y**-shaped).
4. Incomplete fracture—infraction (very rare).
5. Fracture of the carpal end of the radius combined with fracture of the styloid process of the ulna.
6. Fracture of the carpal end of the radius combined with fissure or fracture of the lower end of the ulna.
7. Fracture of the carpal end of the radius combined with fissure or fracture of the scaphoid bone (also with the ulnar end, sometimes).

All these different varieties may be intra- as well as extra-articular.

8. Fracture of little bone portions (chips), usually extra-articular.

109. The first modification that the Roentgen rays imposed upon the anatomy of this fracture was our own discovery of the simultaneous injury of the lower end of the ulna. (See International Medical Magazine, May, 1897.) In a study of 123 cases of fracture of the carpal end of the radius, fissure of the ulna was found 26 times (nearly always in adults) while the complete fracture was observed 9 times (during the age from 10 to 18 years). Displacement of the ulnar fragment was rarely present. In 4 cases it was, in fact, insignificant. The direction of the line of fissure and fracture was always transverse. The injury had invariably been caused by a fall upon the hand when in dorsal flection, the history of the case invariably pointing to a high degree of external violence.

110. Considering that in a case of simple fissure of the ulna the position of the fragments remains normal, as there is no diastasis, it is easily understood why a correct diagnosis was hardly possible before the discovery of the Roentgen rays. tear may, in fact, be so insignificant that only a very disti skiagraph will show it.

Plate XXXIV illustrates a case of osteoepiphysial separati of the radius combined with fissure of the inner surface of epiphysial end of the ulna in a lad of 16 years who had fall down a stone stairway.

Plate XXXIV was taken while the ulnar margin of the ha was slightly lifted, while a former palmar skiagraph created t impression of a normal, non-ossified epiphysis. Another exp sure, taken in the lateral position, illustrated the displaceme of the fragment markedly. This is another proof of the abs lute need, as stated, of taking at least two exposures in differe positions in fracture cases.

111. Another technical point deserving attention is that the exposure is made immediately after a fracture is sustain the fracture line is often not well marked, especially so if the is no displacement of the fragment. After a few days, when t callus formation begins, the line is more marked. The fi skiagraph of the case described, for instance, which show hardly any evidence of the presence of a fracture, was tak 1 hour after the injury. The diagnosis of fracture could made without the aid of the Roentgen rays in this case, but t simultaneous injury of the ulna would certainly not have be recognized by the old method.

Plate XXXV illustrates the case of a lad of 18 years who f from the roof of a small house. When the patient first ca under observation, 24 hours after the injury, there was consi erable swelling of the wrist and marked deformity, which w especially marked at the outer (radial) aspect of the wrist. the ulnar surface a slight irregularity was noticeable. The s agraph showed a considerable displacement of both bon which were in a state of splintering, and a transverse fract of the scaphoid bone. Naturally, the displacement yielded forcible bending under anesthesia. A second skiagraph, tak 3 weeks after refracture, showed ideal apposition of the ul fragments and fair restitution of the radial.

It was only in five of the cases of simultaneous ulnar fissure or fracture that there were any indications of mobility, and even in these cases the indications were so slight that no diagnosis could have been made without the aid of the skiagraph. Of course, as soon as the skiagraph has given a clear anatomic representation of the condition the palpatory impressions become more certain.

112. In view of the anatomic relations, it is natural that ulnar crepitus was never observed in these cases. Sometimes a slight ulnar deformity was noticeable, which was undoubtedly due to the presence of the bloody effusion within the fissure line. The tenderness localized in this sphere harmonized with this assumption.

From the study of these cases the conclusion may be drawn that, in many cases of fracture of the carpal end of the radius producing the so-called sideward pushing of the ulna, there is in fact a fissure or fracture of the ulna which, on account of its insignificant clinical signs, was not recognized in former years. We have no doubt that with the greater popularity of the Roentgen rays the comparative frequency of the injury will be confirmed by many physicians.

113. It should be borne in mind that only a very good tube clearly reproduces the presence of a fissure. A soft tube should be chosen and the exposure should be long enough to show the structure of the bones distinctly and the soft tissues hardly at all, as, for instance, in Plates III, IV, IX, and XII.

It has repeatedly occurred that on account of a mediocre skiagraph a fissure line was not detected which appeared well pronounced in a blameless one. Such facts explain very well why some surgeons disputed the reliability of other fellow observers. Dr. A, for instance, insisting upon his diagnosis, and properly so, while Dr. B, with his poor skiagraph of the same case, asserts that he did not find the fissure line. Of course, Dr. B's opinion is thoroughly honest, but absolutely erroneous, nevertheless.

Especially during the first few days after the injury the presence of a fissure is more easily overlooked than later, when callus formation begins. Only the most thorough observation brings out the necessary points with clearness, and it may be repeated that two synchronous exposures must be taken—one in the dorso-palmar and one in the lateral radio-ulnar position. It is also advisable to make several exposures during different stages of after-treatment. Now we hear a number of confrères say: "This is all very nice and interesting, but wherein does the practical benefit of this detailed anatomic knowledge consist?" To this we must reply that the practical benefit is enormous, since we now understand why simple fissure heals under or in spite of any treatment. Wherever no tendency to displacement exists, no replacement or, to use an ordinary term, no reposition is required.

If the surgeon, led by anatomic knowledge, does the same that the quack does on account of his ignorance, namely, leave the healing process to nature, the same good result may finally be obtained. The scientific treatment of fissure will not alter any of its mechanism, but it will, at least, have the value of giving greater comfort to the patient. Such comfort is obtained by encircling the wrist by a bracelet of moss-board. This appliance immobilizes the wrist sufficiently, and at the same time it permits enough motion to counteract the formation of adhesions in the sheaths of the tendons. The patient carries his hand in a sling in such a manner that the ulnar margin rests on it. Thus, free motion of the hand is permitted. The patient is told to move his fingers as in playing the piano, and we found it very useful to advise him to grasp marbles of moderate size and to roll them around in the palm of the hand. Patients are generally willing to keep these marbles in their pockets, and play with them while reading, conversing, or walking around. If motion is thus kept up constantly the massage treatment, as well as forcible motion, can be dispensed with, and recovery is perfect in 4 weeks or even before.

In complete fracture without tendency to displacement, a plaster-of-Paris dressing may be applied immediately after the injury is sustained. But whenever displacement of the

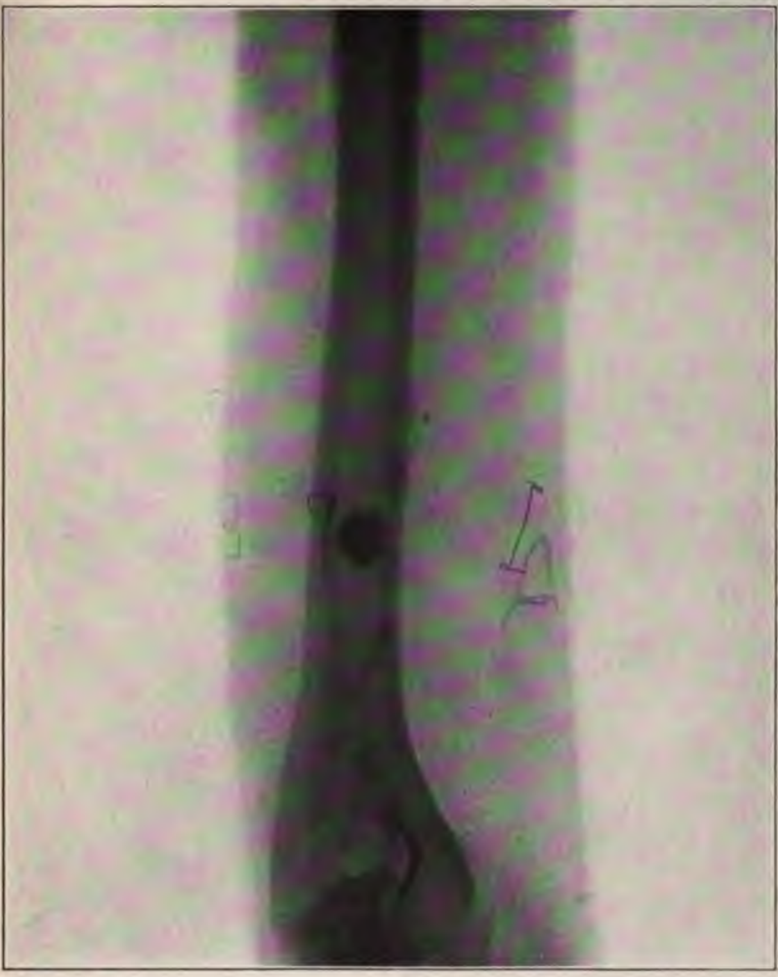

PLATE XXVIII.

Localization of Bullet in Upper Arm by Wire Letters.

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fragments takes place, accurate reposition is the condition sine qua non. This is done best by forced extension, the hand being grasped as in a firm hand-shake, with a downward pressure by the surgeon's thumb, while counter-extension is used on the forearm, which is flexed rectangularly. If an assistant is at hand, the surgeon grasps the four fingers with his left and the thumb with his right hand, while the assistant uses counter-pressure at the elbow. If this procedure should fail, anesthesia must be employed. If there is simultaneous injury of the lower end of the ulna showing displacement, like in Plate III, for instance, great care must be taken to press the fragment into its normal place.

114. Even in multiple fractures, especially in the much dreaded **T**-shaped variety, the articular arch of the radius may be restored by repeated efforts of reposition controlled and corrected by the Roentgen rays. Even the routine surgeon is often astonished to find, after he thought he had accomplished a perfect reduction, how badly he has succeeded in his alleged reposition, one small item generally having been overlooked by him. Fortunately malposition can often still be corrected after 2 or 3 weeks.

Keeping the fragments well adjusted in a proper position is quite difficult sometimes. We have, however, always been able to secure this by very simple methods. A long adaptable wire splint is applied while forced traction is made; the splint reaches at the flexor side of the arm from the tip of the fingers to the elbow. If the direction of the displacement is *upwards* (silver-fork shape), a pad of adhesive plaster is attached to the dorsal integument above the fragment. Then a short, narrow splint of wood is applied on the dorsal aspect of the arm, reaching from the metacarpophalangeal joint to 4 inches above the wrist, and is kept pressing downwards by the application of a gauze bandage.

If the tendency to displacement is *downwards*, the same procedure is carried out in the opposite manner, the wire splint being applied on the dorsal, and the wooden splint on the palmar side of the arm.

If the displacement be *sidewise*, which is most marked when there is a simultaneous injury of the ulna, immobilization must be carried out on entirely different lines. The adhesive plaster pad must then be applied laterally to the fragment, two long, narrow, wooden splints being used at the same time. One of these splints, being a little broader than the diameter of the bone, begins at the metacarpophalangeal joint of the thumb, and the other at the same point of the little finger. Both extend up to the elbow, the same as the long wire splint. If there should be any displacement in the opposite direction, the pad must be applied on the ulnar side. No dorsal splint is used in this variety. After the dressing is finished, the skiagraph verifies the proper position of the fragments. In case the tendency to displacement cannot be overcome, a plaster-of-Paris dressing is applied, while forcible extension and counter-extension are used. Whether the position of the fragments is correct should be ascertained by the rays after the plaster-of-Paris dressing is applied.

If, after the lapse of a week, agglutination of the fragments is obtained and no deformity is evident, then the soft tissues must receive consideration. It is only then that short splints are in order. They consist of well-padded pieces of wood extending from the metacarpophalangeal joint up to the middle of the forearm. After another week a bracelet, such as is recommended for the treatment of simple fissure, is so applied as to permit of the free motion of the fingers (see Art. 113). The patient is told to move his fingers as in playing the piano; also to use the marbles as described in the treatment of the fissure.

After the third week massage treatment is indicated, active as well as passive motion of the joint being employed at the same time. The results of these simple methods are just as good if not better than those obtained by any of the numerous much complicated apparatus often advised for the same purpose. If all the points of these manipulations dictated by simple common sense are observed, and if their proper execution is certified by the skiagraph, surgical clinics will no longer furnish so much testimony of deformities and functional impairment following fracture of the carpal end of the radius.

Of course, for the rich man who does no work and for the laborer who does only rude work, the faulty position may be of little importance. But whoever must do delicate work will be greatly damaged by even a small degree of functional disturbance. In fact, it is the displacement of the fragment, be it even very small, which causes the chain of later disturbances.

115. These doctrines are so simple that it seems almost unnecessary to repeat them. And yet they are frequently violated. The functional impairment following some fractures, especially the formation of adhesions in the vicinity of the joints, has led a number of surgeons to enunciate this dogma: "The most important part in the treatment of fracture is the treatment of the soft tissues." They claim, in other words, that because the function of the soft tissues—for instance, of the tendons—is impaired after a non-reduced fracture, the soft tissues should have received more attention instead of the displaced fragment having been simply reduced to where it belongs. Nothing, in fact, is more contrary to common sense than this dangerous maxim, which is based on correct observation, but incorrect interpretation. It should always be considered that the relations of the soft tissues to the bones are like that of the clinging vine to the sturdy oak.

Galen says that the bones give the human body form, erectness, and firmness. It is evident that an injury of the bones impairs these three fundamental factors. The most important step toward repair must thus be taken in the foundations rather than in the superimposed structure.

If there is displacement of the bone fragments, undue pressure is necessarily made upon the soft tissues; *non-reduction means persistence of pressure*, the unfortunate consequences of which are well known. *Reduction means the relief of pressure.* Of course, the act of injury cannot be undone by the mere cessation of pressure; but the influence of the injury on the soft tissues—the influence of the pressure, in fact—lasts only a short time, and is insignificant after early reduction; there is then but little inflammation, and consequently little exudation, and therefore repair is easy. This means that the premises of adhesion formation are wanting, and clinical observation shows that if there was perfect reposition, the joint as well as the sheaths of the tendons are found free, provided the immobilization has not lasted for an extraordinary length of time. In such cases of severe functional disturbance of the joint produced by the agglutination of the fragments in a displaced position we have repeatedly succeeded in reducing the deformity by osteotomy performed under the guidance of the Roentgen rays. In every instance the functional result has been very satisfactory.

116. In addition, it may be urged that there is another and frequent simultaneous injury, namely, the fracture of the styloid process of the ulna, which was discovered long before Roentgen by Nèlaton and Velpeau, but has often again been disputed.

The Roentgen rays bring the great old French surgeons to honor again. Our statistics show a participation of the styloid process in 31 per cent. of the cases. Kahleyss, in his monograph, finds a frequency of 78 per cent., which seems to us to be rather high.

In this country, especially Pilcher, Freeman, Corson, Thomas, Don, Haughton, and Colton have contributed their share to the better understanding of this condition. How important early recognition of the displacement of the broken styloid process is may be evident from the case of a woman of 30 years who had sustained a fracture of the carpal end of the radius, but which was not skiagraphed until 8 weeks after the injury, when she still suffered from a stiff, swollen wrist. The skiagraph revealed inversion of the styloid process of the ulna, which explained the intense pain caused by any effort of bending the wrist-joint. Had this condition been recognized at an early stage, a small amount of pressure would have sufficed to push the fragment into its proper position, while after the elapse of 8 weeks perfect restitution could be expected only by removing the little obstacle with the chisel.

117. Another interesting injury is the fracture of some of the carpal bones, at first discovered by Destoit and Gallois. In realizing that the fracture of the carpal end of the radius is not only expressed by a tear, but also that it is produced by a

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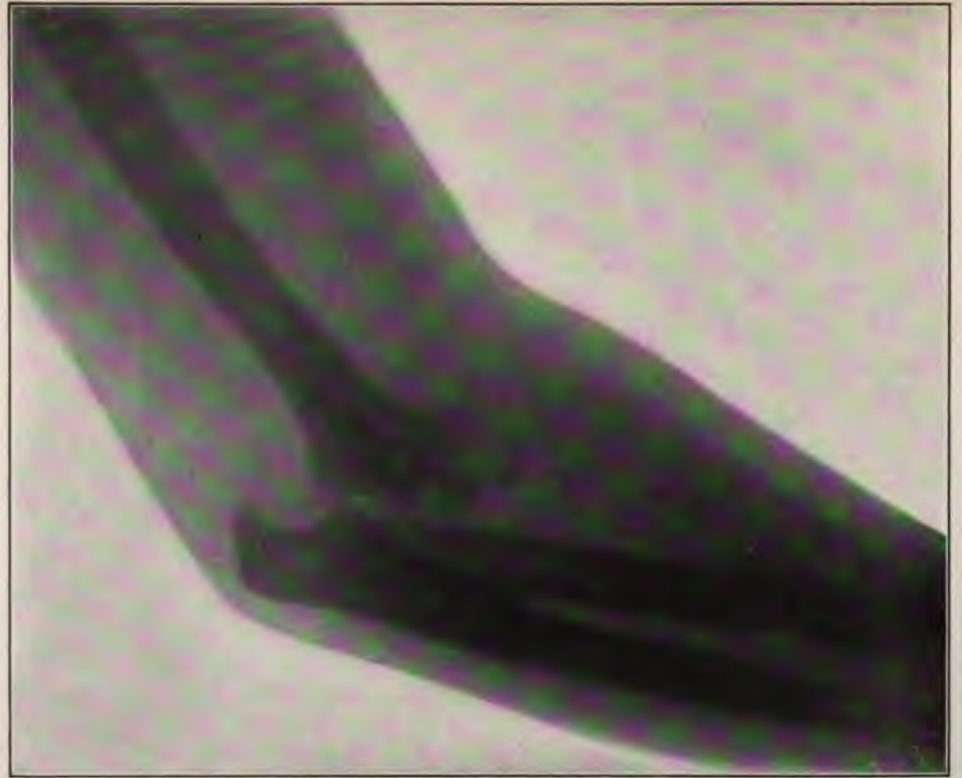

PLATE XXIX.

Backward Dislocation of Elbow.

combination of tearing, pushing, and counter-pushing, it is easily comprehended why the effect of the violence is not confined to the radial epiphysis but also either extends to the ulna (ulnar inversion of the radial fragment described above) or is transferred to the carpus. It has been maintained that the preference is for the semilunar bone (Gocht, Kahleyss). Destoit and Gallois, also, found fracture of the unciform bone. Most of these reports, however, refer to the isolated fracture of these bones. It seemed repeatedly that we had detected these injuries so long as we had a palmar exposure only, but lateral projection showed that the shadow of the adjoining carpal end had deceived us. ("Errors Caused by the False Interpretation of the Roentgen Rays," New York Medical Record, August 25, 1900.)

118. But another injury, namely, *transverse fracture of the scaphoid bone*, was observed in 9 per cent. of our cases. In realizing that the scaphoid is the most important of the carpal bones articulating with the radius, it can easily be understood that the same mechanical combination following external violence, as alluded to in connection with ulnar coinjury, holds good in regard to the scaphoid bone, viz., that the pressure is continued to its arch, which must then yield. The direction of the force is straight, in this instance, instead of being sidewise, as in ulnar coinjury, the hand being held in pronation and radial inflection. This also explains the enormous intra-articular effusion sometimes present, which is responsible for the great tendency to the formation of adhesions in these cases. In all the cases observed by us an extreme degree of violence was the etiological factor.

Based on this experience, we may venture to call this injury a typical one, found as a consequence of an extreme degree of violence. Previously, the extensive swelling caused by the abundant effusion was attributed to the radial injury only. It is this injury that is especially prone to cause bony ankylosis of the wrist. Now, in diagnosticating this injury at an early stage, we possess the power to counteract this occurrence by early motion.

119. The more we learned to modify our diagnosis by the Roentgen rays, the oftener have we found that the most convenient diagnosis of contusion or distortion in many instances is, in fact, nothing else but a makeshift for a fissure or fracture. Aside from the fracture of the whole styloid process of the radius itself, the stripping off of small bone portions is of frequent occurrence. In such cases massage treatment is manifestly inappropriate; the treatment to be carried on is the same as for the treatment of fracture, viz., immobilization. This should be kept up at least for the first week after the injury and after the little fragments were redressed.

Such chips are sometimes not larger than the head of a pin, and if they are separated from the dorsal or palmar surface of the radius they may not be at all conspicuous on the skiagraphic plate when it is taken from the palm or the dorsum, the thick shadows of the radius veiling them. A lateral exposure will, of course, show them distinctly. A small bone-chip may be seen associated with non-displaced fracture. If the massage treatment, so commendable in contusions, is used in these cases, it is not surprising that the patient becomes rebellious. The Roentgen rays explain this phenomenon well. It is, in fact, not at all indifferent whether a simple bloody effusion or keen edged bone fragments are kneaded.

120. The study of the various diseases and injuries of the hand was greatly benefited by the discovery of the rays. A large number of alleged dislocations and contusions are, in fact, either complete fractures in adults or separation of the epiphysis in children. Especially fractures of the metacarpus proved to be by no means as rare as was thought formerly. In most cases displacement of the fragments being absent and the other metacarpal bones serving to a certain extent as splints, it is natural that the results in these cases were nearly always good no matter what treatment was employed; the *post hoc, ergo propter hoc* being enough for the superficial observer. If, however, he had used the Roentgen rays he would have been not a little surprised to find in such a case the evidence of a fracture; while at the same time he could congratulate himself that in spite of his treatment for simple contusion the result was so perfect.

In the event of displacement the result would be somewhat different. If the displacement is in the dorsal direction, it is not only easily recognized, but also reduced and kept in place without difficulty by the coaptation splints. But if the displacement, as it often occurs, is sidewise, the result may be very unsatisfactory, the remaining deformity and disturbance of function being considerable. If a common laborer is concerned but little inconvenience may be caused by it; but if a person whose hands must do delicate work, like a musician, watchmaker, cabinetmaker, or last, but not least, a physician, for instance, is the victim, badly united metacarpal fragments of the right hand may seriously interfere with his professional work.

Reduction of the displaced fragments never offers any insurmountable obstacles; but to hold them in place is a far more complicated task, and the recurrence of the displacement under the usual immobilizing methods shows their insufficiency in the end.

121. The question now is: what is to be our guide in estimating the value of a given immobilizing method before consolidation can have taken place? In former years we used to judge the value of one or the other method by the final result. But, now, just as we estimate the value of a germ-destroying method first of all by bacteriological experiment, so we are able to judge by irradiation from the very beginning. If the immobilizing dressing is perfect, the formerly displaced fragments must be found in exact apposition when skiagraphed through the dressing. Various experiments have shown that the metacarpal fragments are invariably held in place by elastic pressure. For this purpose two rubber drainage tubes of moderate size are chosen, which are lightly pressed into the adjoining interosseous spaces so that they fill them up to a certain extent. They are kept in place by strips of adhesive plaster. Thus the recurrence of the displacement is prohibited. The whole is surrounded then by a moss-splint, a material that

after [illegible] dipped in cold water adapts itself to the co
of the hand like a plaster-of-Paris splint, over wh
possesses the great advantages of being absorbent and
lighter.

[illegible] case of a young Italian who sustained a fractu
[illegible] metacarpal bone in its middle as a result of d
[illegible] his brother in the face with his fist), con
[illegible] displacement was produced. Reposition
[illegible] and the fracture area was carefully s
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[illegible] of the fingers nor any sign of discon
[illegible] examining the metacarpus 2 weeks later wit
[illegible] splints. it was found that the fragments
[illegible] again. Other means of immobiliza-
[illegible] considered. After filling up the interosseous
[illegible] metacarpal bone and the little finger
[illegible] third one on the other with two rubber
drainage-tubes, a skiagraph was taken, which showed the fragments in ideal apposition. Shortly afterwards the rubber tubes were removed and the displacement recurred at once. From this we learn that it is unwise to rely upon the old dictum that metacarpal fractures show perfect consolidation after 3 weeks. We should consult the Roentgen rays before satisfying ourselves as to the question of impeccable union.

122. Recognition of the various types of *dislocation of the thumb* has also become easy. In former years old non-reduced dislocations of the thumb were a frequent occurrence at surgical clinics.

Plate XXXVI shows dorsal dislocation of the second phalanx of the thumb in a woman of 26 years. Reduction could still, after 3 weeks, be accomplished by the use of a strong blunt traction-forceps. *Fractures of the phalanges* were also often overlooked. While a thorough examination should always reveal the presence of a transverse fracture of the phalanges, the longitudinal type could not be suspected under ordinary circumstances. Plate XXXVII shows the third phalanx of the ring

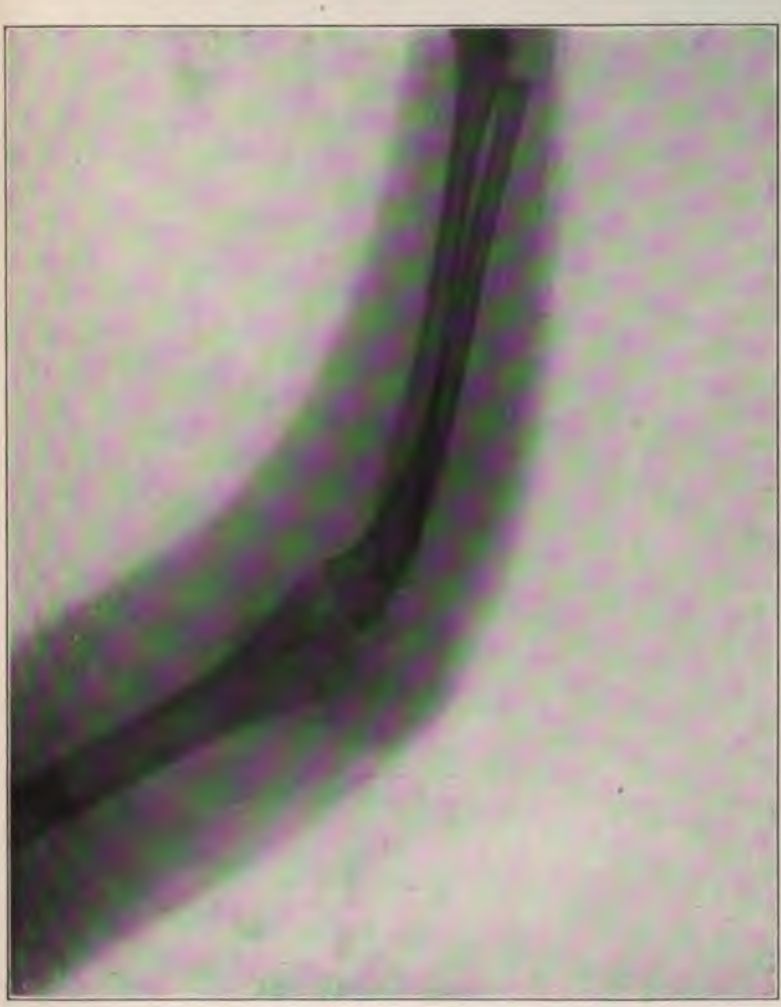

PLATE XXX.

Osteoepiphysial Separation of the Lower End of the Humerus.

finger of a lad of 15 years split nearly in halves. The skiagraph suggested pressing the two fragments together and keeping them in apposition by a strip of adhesive plaster. We confess that we never knew of the existence of this fracture-type before.

123. *Tuberculosis* of the carpus, metacarpus, and phalanges, frequent in children, can be well studied and treated under the guidance of the rays (see Art. **136**).

124. It was our privilege to discover a pathological condition (tenontitis and tenontothecitis prolifera calcarea) which, as far as our knowledge goes, has never before been described. It concerned a Russian tailor, age 42 years, who noticed a small and painless swelling formed in the dorsal surface of his right hand 11 years before. The size of this swelling increased gradually, but sometimes it seemed to be somewhat less. At last it became quite large, but until it grew painful no medical advice was sought.

When first examined a globular tumor was noticed on the dorsum of the right hand, the size of which corresponded to that of a moderately large apple. Its surface was red, its consistence irregular, some parts of it being hard, while others appeared soft to the touch. The center of the tumor was occupied by a large ulceration, which was surrounded by several fistulous tracts from which turbid sero-pus issued.

The first impression was that the tumor represented an osteosarcoma and it was feared that speedy amputation would be indicated. It was decided to consult the Roentgen rays, which proved to be a valuable means of information, since the true condition was at once precisely defined. A skiagraph taken under the influence of intense irradiation showed that the third metacarpophalangeal joint was the seat of a focus of inflammation. The first phalanx was grown together with the metacarpus. The cortex of the condylar side was totally destroyed, appearing as if scooped out with a gouge. By faint irradiation the outlines of the tumor appeared well marked.

A third skiagraph taken under powerful irradiation and a short exposure showed the bones faintly, but permitted distinct recognition of the various shades of the tumorous portions.

The light areas showed the suppurating portions while the d shades corresponded to the calcareous areas. These, as shown by the subsequent operation, were the predominating eleme of the tumor. It now became evident that there was a chron inflammatory process probably of a tuberculous nature.

The extirpation showed the defect of the bone filled wit yellow cheesy masses, the synovial membrane being partiall destroyed at the same time. But the most surprising feature of the condition was that the extensor tendons of the digits, excepting the thumb, appeared as if cemented into one mass of mortar. In dividing this mass the knife caused a loud grating sound.

Of the tendon on the third finger only a few rudimentary fascicles had remained, so that it had to be sacrificed entirely. The fascicles of the second and fourth extensor tendons were kept apart by the concretions. They were, in fact, so much incrusted that only a small portion could be felt. The weight of the whole amount of the calcareous mass removed proved to be 80 grains.

Microscopical examination showed round-cell granulations and the presence of staphylococci, but no evidence of tubercle bacilli. There were also deposits of phosphates and carbonates of calcium. The fragments of the tendons showed granulation of the circumfascicular and the intrafascicular connective tissues.

Hematoxylin colored the degenerated tissue dark-brown violet, and picrocarmin changed it into red. Recovery was slow and did not become perfect until 6 months after the operation.

Now, what was the integral character of the disease? There was a much degenerated (cheesy) tissue in the state of necrobiosis which seemed to have a sort of magnetic effect, so to speak, on the dissolved calcareous salts, inducing them to amalgamate. Such petrifactions are found in tuberculous (cheesy) foci of the lungs and not infrequently in endocarditis, pericarditis, in old pleuritic bands, uterine myomata, and in renal epithelium. In the walls of blood-vessels as well as in degenerated thyroid glands we have had an opportunity, by means of the Roentgen rays, to define the mode of petrifaction.

The tendons and their sheaths seem to be but seldom the seat of predilection for calcareous deposits. Still, with the increasing popularity of the Roentgen rays, more light may also be thrown upon the pathology and significance of this hitherto unknown disease for which we suggest the name of tenontitis and tenontothecitis prolifera calcarea. (New York Medical Journal, April 27, 1901.)

125. As previously mentioned, the great scientific and practical value of Roentgen rays is also evident in the study of *congenital malformations of the bones.* Skiagraphy of the extremities especially has given more valuable information than dissection. The exact anatomic diagnosis that it enables us to make informs us whether surgical interference in a case of malformation is possible and, if so, outlines clearly our modus operandi beforehand. The ingenious operations of Bardenheuer (division of the ulna for carpal implantation) and von Eiselsberg (transplantation of the toe), and the work of Kirmisson, Vulpius, Middleton, Pagenstecher, von Bardeleben, Joachimsthal, Schede, Lambertz, and Grunmach furnish most brilliant testimony to our progress in this direction.

126. Polydactylism.—Fortunately, the most frequent abnormality is the one that can be most easily remedied, namely, polydactylism. If there is but a rudimentary finger attached loosely by a pedicle and containing no phalanges at all, removal is very simple.

But when, as is the rule, there is a true supernumary digit articulating with another phalanx or the head or side of a metacarpal bone, the site of exarticulation must be well known before the operation. Otherwise, the better developed phalanx may be sacrificed.

127. Syndactylism.—Syndactylism, while not so frequent as polydactylism, also represents a large group of cases of malformation of the upper extremity and is likewise amenable to operative interference.

In a case of syndactylism in a boy of 4 months the second, third, and fourth digits appeared to be fused together, each one of them, however, possessing its own nail. The skiagraph showed fusion of the first and second phalanges of the third and fourth digits, while their third phalanges were free. The little finger was more developed than the slightly deformed thumb. The carpus was not yet ossified, and showed no shade therefore. Under the guidance of the Roentgen rays it was easy to divide the phalanges. The middle finger was protected easily by a large longitudinal flap from the dorsal surface of the hand. The other two fingers were covered with their integument, longitudinal flaps being formed from the palmar surface for the second finger, and another one from the dorsal side of the fourth. The final result was good.

128. Congenital Deficiencies.—Congenital deficiencies are naturally much less amenable to correction. But that surgery is not without resources even in desperate cases of this kind is made evident by the transplantation of a toe to the hand, successfully undertaken by von Eiselsberg.

In *brachydactylism*, combined with ectrodactylism, the Roentgen rays have proved to be of great value. In the case of a boy, age 3 months, there were five rudimentary fingers. The skiagraph showed the presence of one phalanx of the thumb and one of two phalanges of each of the other fingers.

Under the guidance of the Roentgen rays a flap operation was performed, on the principles set forth in the case described in Art. 127, between the first and second finger rudiment. Thus a fairly good thumb was created. The case, however, offered two more points of interest. In the first place there was a congenital fracture of the ulna and radius at their lower third, as was also illustrated skiagraphically. The forearm could be bent easily at the seat of the fracture. After wiring the fragments, union became perfect.

There was, furthermore, congenital constriction at the region of the surgical neck of the humerus, where a deep furrow encircled the whole circumference of the arm. Palpation was unable to detect any soft tissues between the integument and the bone. An exploratory incision revealed the presence of fragments of the biceps, triceps, and deltoid muscles. Their

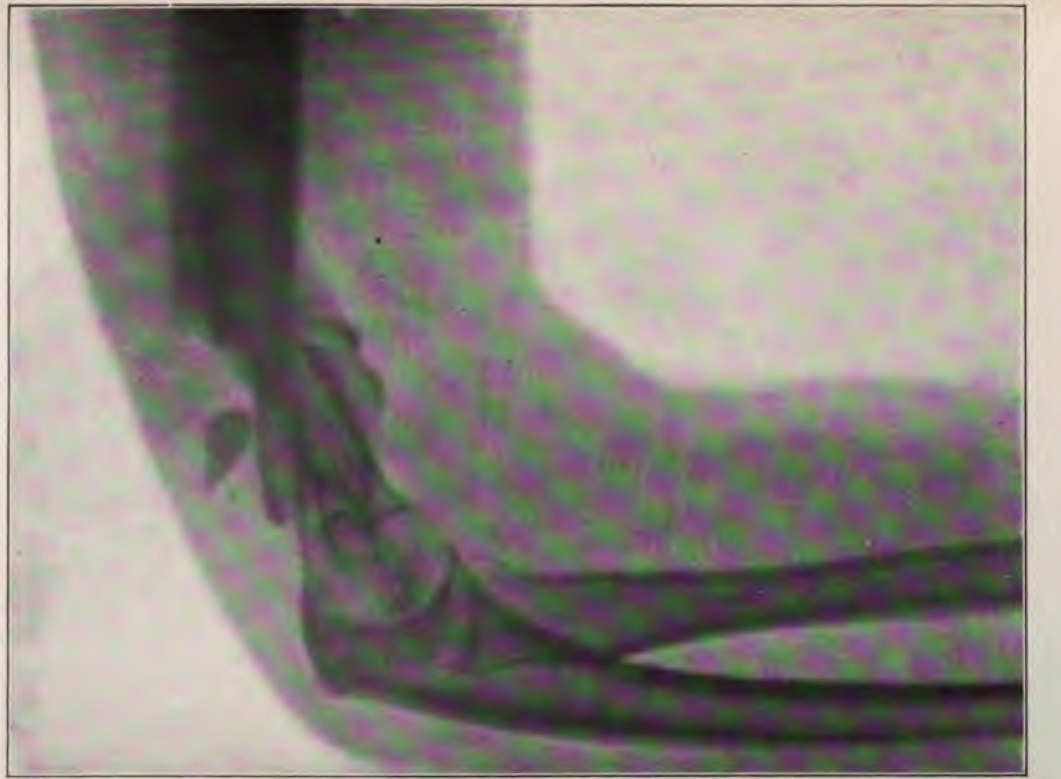

PLATE XXXI.

Multiple Fracture of the Lower Third of the Humerus.

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edges were refreshed and united with catgut. For relaxation two deep wire sutures were introduced from without. The result is fair according to the last report, 18 months after the operation.

It may be added that the otherwise well-developed hand showed a moderately deep constricting furrow near the metacarpophalangeal junction of the middle finger, which did not seem to demand surgical interference since the skiagraph showed its integrity otherwise.

It seems to us that this special branch of surgery does not receive the attention it merits. Considering that in the lower animals, as long as in the embryonic stage, regeneration of large portions of the head and trunk are possible, it should be expected that the new-born child—in a smaller proportion of course—also offers more chances for regeneration than the adult. If the germinal layer is only present, further development of the tissues can be looked for. If a part of a phalanx is properly severed, its individualization is a matter of great probability provided the bridge remaining has preserved sufficient vascularity for nutrition, that there is no overextension of the flap, and that the most minute aseptic precautions are taken.

Foreign bodies are easily shown in the hand, especially needles in the palm often coming under the observation of the busy practitioner. Plate XXXVIII is only presented to show that even the eye of a small needle can be well shown.

129. Remedying a Club-Hand.—In a case of congenital club-hand associated with absence of the radius and ulna, only three fingers and three metacarpal bones were present, as became evident by skiagraphic examination.

The left arm of the boy was normal with the exception of the thumb, which was partially ectrodactylic. An attempt was made to improve this deplorable condition by creating a thumb after the principles carried out in the case just described. For this purpose a dorsal incision was made down to the first metacarpal bone, which was divided longitudinally, thus making a kind of bifurcation. The phalangeal end was severed entirely, but the carpal end, after being fractured longitudinally, was left in slight connection with the metacarpal bone. Thus a new bone was obtained that was surrounded by dorsal as well as palmar flaps. There was little trouble during the after-treatment. How far this new fourth finger can be utilized can, of course, not yet be known, the child still being under treatment. (See "Congenital Malformation of the Upper Extremity," New York Medical Journal, June 29, 1901.)

INFLAMMATORY PROCESSES AND NEOPLASMS OF THE BONES AND JOINTS.

130. Many limbs have been sacrificed by unnecessary amputation and many lives have been lost by deferred amputation on account of errors in differentiating the various inflammatory processes from new growths of the bones and joints. The Roentgen rays have opened entirely new fields in this sphere. If they are not always able to give a positive answer, they often by the way of exclusion give a chance to arrive at a correct diagnosis.

If in a case of obscure swelling of the knee-joint, for instance, the Roentgen rays reveal nothing else than the absolute integrity of the joint, osteitis, tuberculosis, syphilis, or a bone-injury can be excluded. It is certain then that only the soft tissues are involved. Thus we may, in conjunction with other clinical symptoms, be satisfied that we have to deal with a rheumatic swelling or a neoplasmoid formation of the soft tissues only. But in many instances the Roentgen rays give positive information.

131. Periostitis.—Again, in periostitis as well as in osteomyelitis the skiagraphic signs are well marked. Abscesses can not only be localized, but their extent is so well outlined that the technical steps of the operation can be definitely traced in advance. The feeling of security the surgeon has while proceeding under the mentorship of the skiagraph gives a satisfaction unknown in former years, when often the whole femur had to be exposed simply in order to ascertain whether all foci were detected. If the Roentgen rays show but one focus, no other regions of the bone need be attacked.

In such cases a preceding trauma often opens the avenue of infection. The pain, the edema, the fever, and general debility may be sometimes so little marked that differentiation becomes difficult. The skiagraph not only clears this difficulty of diagnosing this disease, true etiology of which is still so obscure, but it also furnishes a trustworthy guide for the operative technic at the same time.

132. Osteomyelitis.—Osteomyelitis is of a decidedly infectious character, generally due to the invasion of the staphylococcus, which fortunately has a tendency of forming circumscribed foci in the vascular tissues of the bone, viz., the medulla and sometimes the periosteum. The predilection of osteomyelitis is for the long bones of young individuals. It is self-evident, therefore, that the early recognition of osteomyelitic foci renders the prognosis of their evacuation extremely favorable.

In the case of a woman of 20 years the slow onset of the symptoms did not seem to indicate an acute inflammatory process. Pain being present only temporarily, the fear of a malignant growth was apparently not unjustifiable. The skiagraph at once did away with all anxiety, since it revealed the presence of periostitic proliferations and a circumscribed osteomyelitic focus at the middle of the humerus. The focus was easily exposed by the chisel under the mentorship of the skiagraph. That the skiagraph had also spoken the truth by demonstrating the integrity of the remaining portions of the humerus was shown by the speedy recovery of the patient.

The focus was distinguished by its light shade in the midst of the dark shade of the cortex. The regularity of the cortical line distinguished it from osteosarcoma and the absence of distention from osseous cyst.

133. Necrosis, and other later stages of inflammatory processes can be represented still more distinctly. The size and shape of a sequestra can be easily made out. It can furthermore be ascertained how they are located in their bony coffin, whether they still adhere or are exfoliated. Under the guidance of the Roentgen rays extraction is very easy.

In the case of a man of 23 years who had crushed his little finger, amputation was deferred until septic tenonitis an tenontothecitis had developed. The extensive tissue necrosi in the muscular interstices of the forearm necessitated free an deep incisions, which showed the radius as well as the uln denuded of its periosteum. Amputation was therefore authoritatively advised, but nevertheless the chances for further conservative treatment were taken. Fortunately the process becam confined to the forearm and recovery seemed to make rapi progress. Only a small fistula at the dorsum of the forearm di not close. The repeated introduction of a probe did not revea the presence of rough bone, and we were inclined to suppres our suspicion of the presence of a sequestrum. Our surpris was great when the Roentgen rays revealed the presence of large splinter exfoliated from the inner portion of the radius, th surface of which was covered by osteophytes. The direction o the skin incision, slightly oblique, was dictated by the positio of the sequestrum as shown by the skiagraph. When the sequestrum was reached it was found to be covered by thick, fibrou tissue at the upper surface, while the inner and lower surface were exposed. This explains why the introduction of th probe gave no positive information, since it had touched onl the fibrous cover and did not come into contact with the roug lateral or posterior surface. Recovery was perfect 11 days afte the operation. The regeneration of osseous tissues can be wel studied in such cases by the skiagraph.

Foci of the same character are sometimes formed in typhoi fever. They must be treated after the same principles.

134. In diagnosing inflammatory processes in the joint great difficulties are sometimes offered. As stated before, in th case of *acute rheumatism* the integrity of the articular outline are well marked. The same applies to acute inflammatory pro cesses due to infection. In the latter event the distension of th joint by the serous or purulent effusion may be represented b the skiagraph.

In *chronic rheumatic processes* the articular bone line appear somewhat irregular.

In *arthritis* the contours of the bone epiphyses appea

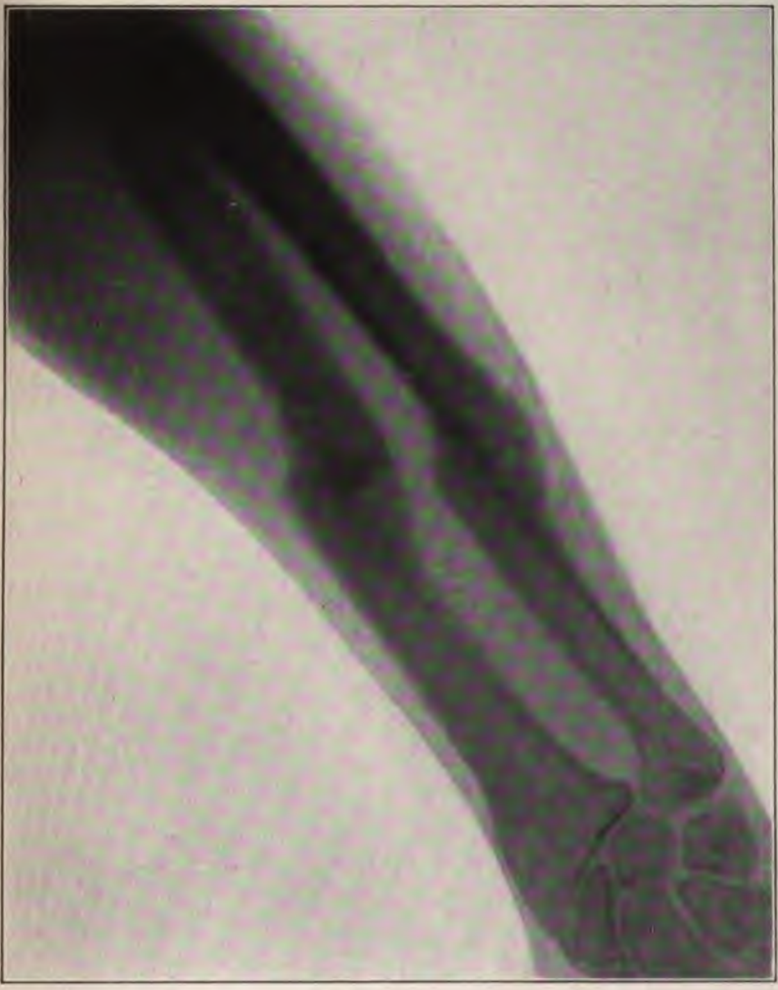

PLATE XXXII.

Deformed Union After Fracture of Radius and Ulna.

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irregular; they appear like indentations on some portions, while others are veiled.

In *arthritis deformans* the osteitic proliferations are especially abundant and are well represented by the rays. The arthritic deposits are recognizable as light shades of the deformed epiphyses, as they consist of translucent uric-acid salts, while their periphery is distinguished by a dark sphere.

Plate XXXIX illustrates the case of a laborer of 50 years who sustained an injury of his elbow 11 years before. He reported that recovery took place after several months and that the elbow had remained stiff ever since. During the last few years inflammatory signs had manifested themselves, which were regarded rheumatic. No other joints were involved. Since then he also had repeated attacks of pain in the elbow-joint. When we examined the patient for the first time we found the elbow very much thickened and fixed at a sharp angle. Pressure below the external condyle caused intense pain. Crepitus, so often found in old arthritic processes, could not be produced in this instance as the joint permitted no motion at all. There were no indications of tuberculosis, syphilis, or gonorrhea.

The skiagraph, Plate XXXIX, revealed the presence of malunion (sideward displacement) of the coronoid process of the ulna, which probably had given the first impetus for the development of the arthritis deformans, which is especially well marked in the external condyle of the humerus. The left condyle shows synosteosis with the olecranon. Removal of the projecting fragment by the chisel, separation of the adhesions, and the partial resection of the external condyle, the seat of predilection for the acute attacks, were advised as therapeutic means.

135. Arthropathia Tabica.—In arthropathia tabica the bone appears eroded as in osteoperiostitis, but at the same time it is considerably distended.

136. Tuberculosis of the Bones and Joints.—In *tuberculosis of the bones and joints* the Roentgen rays not only give information as to the seat and extent of the tubercular areas, but also offer the only means sometimes of differentiation from other affections, the clinical signs of which resemble it. The walls of an intraosseous focus appear thickened. Some portions are translucent and their contours irregular. The articular outlines of a tubercular joint have lost their regularity and appear diffuse, cloudy, and sometimes shaggy (Plate XVII).

In later stages, when cheesy foci have formed, for instance, their areas become translucent. The cortex is sometimes entirely destroyed and leaves the impression of having been scooped out with a gouge. When there is calcareous degeneration the foci appear dark shaded.

In the case of extensive tubercular destruction the eroded and displaced cartilages can be studied. In tubercular coxitis the spontaneous upward dislocation of the femur and the separation of its head in the acetabulum can also be easily recognized.

It need not be said that the early detection of a tubercular focus enables the surgeon to do a conservative operation, while at the late stage of extensive destruction such efforts are futile, as it is sadly illustrated by skiagraphic examination.

137. By realizing that so-called *osteosarcoma* is the most frequent of morbid osseous growths, and that of all tumors, sarcoma offers the gravest prognosis, the importance of a thorough diagnosis need not be emphasized. The matrix of osteosarcoma, like that of all osseous growths, is either the periosteum or the medulla in combination with the tissue originating from their proliferation.

Periosteal sarcoma is of moderate hardness and contains either round, spindle, or polymorphous cells. It attaches itself to the bone laterally, but may in its further development encircle it entirely. Periosteal sarcoma may become a real osteosarcoma at a later stage, when osseous trabeculæ are formed.

The skiagraph of periosteal sarcoma is characteristic, since it shows fine spiculated trabeculæ that radiate from the surface. Periosteal sarcoma spreads rapidly and is highly malignant. Whenever the diagnosis *periosteal sarcoma* is made, amputation should be insisted on.

138. Various Classes of Myelogenous Sarcoma. Sarcoma originating from the medulla is called myelogenous and is of a less malignant character. It may be classified as *soft*, *hard*, *alveolar*, and *multiple*.

139. Soft Myelogenous Sarcoma.—The soft myelogenous variety shows the ordinary sarcomatous texture. Its predominating feature is the presence of round cells. It has a decidedly more benign character than the periosteal type. Therefore, it justifies a conservative attempt, that is, extensive extirpation. It produces carious destruction of the spongy portion, which may cause spontaneous fracture. At a later stage the osseous shell will yield to the spreading sarcomatous tissue.

This variety has a predilection for the long bones, especially their ends, and predominates at the lower epiphyses of the femur, tibia, humerus, and radius. Skiagraphs of the soft myelogenous variety show the absence of osseous tissue, small fragments of which are sometimes left here and there.

In the case of a woman, age 28 years, who had fallen on her hand when it was in dorsal flexion, the faint outlines of bone-shell in a soft myelosarcoma were shown. The swelling resulting from the injury produced the impression that a fracture of the carpal end of the radius was sustained.

Three months after the injury, when the patient came under our observation for the first time, a slight deformity was noticed just as it is observed in a badly united fracture of the carpal end of the radius. But the consistency of the epiphysial end was soft. The skiagraph failed to show the evidence of bone tissue, only one small remnant being left at the outer aspect of the radius. Resection was advised, but before the patient submitted to it another month had elapsed, during which time the neoplasm had grown to a great extent. The result was reported as being fair 8 months after the operation.

140. Hard Myelogenous Sarcoma.—The hard myelogenous variety, generally called *endosteal*, or *central*, sarcoma, also shows the ordinary sarcomatous structure. Its distinguishing feature is its fibrous texture and the presence of spindle cells. Some portions contain various tissues; the spindle-cell tissues often containing giant cells. If smaller or larger bone trabeculæ are produced, it is called *osteosarcoma proper;* if there are calcareous deposits, *petrifying sarcoma;* and if the tissues become vascular, a *telangiectatic sarcoma* will be formed, so that it may be mistaken for an aneurism.

In later stages, when there is a regressive metamorphosis, fatty or cystic degeneration may take place. Then these neoplasms that occur, especially in the femur, tibia, and inferior maxilla, may attain an enormous size.

The skiagraph of osteosarcoma proper shows more osseous tissue than the former variety, but its outlines are very irregular. Osteosarcoma proper usually commences near the epiphysis of a long bone.

The skiagraph of an osteosarcoma proper in a woman, age 40 years, showed the destruction of the lower third of the radius and of a large portion of the carpus. Resection was performed; the result was perfect, as was illustrated by another skiagraph taken more than 4 years after the operation, which showed the regeneration of the osseous tissue.

141. Alveolar Myelogenous Sarcoma.—The alveolar variety is characterized by its alveolar stroma, which contains nests of large cells. They have a predilection for the bones of the skull and the trunk.

142. Multiple Myelogenous Sarcoma.—The multiple variety (also called *myeloma*) is characterized by the presence of numerous whitish foci, which consist of small, round cells. It has the same structure as the lymphoid sarcoma and is almost exclusively found in very old individuals, for whose skull and trunk they show the same predilection as the former variety.

The skiagraph of the alveolar, as well as the multiple type, shows the foci as light irregular shades. The structure of their type, especially their manner of destroying the preexisting bone-tissues, the thin osseous walls, and the trabeculæ formation, is the standpoint for their skiagraphic study. The intra-osseous tension is responsible for the expansion of the compact osseous layer, which is thus made gradually weaker and at last almost entirely disappears. Thus, we see that it is the abnormal and

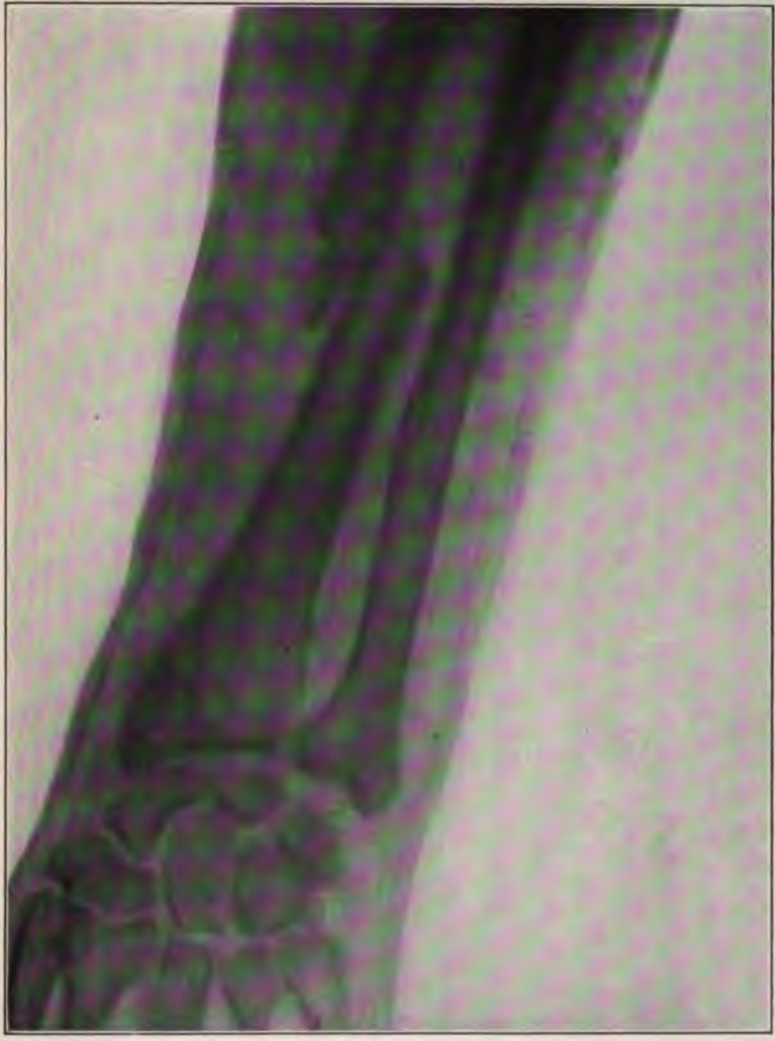

PLATE XXXIII.

Fracture of the Shaft of the Radius, Showing Imperfect Reduction Through Plaster-of-Paris Dressing.

indefinite outline, or even the entire absence of osseous cells, the cortex especially disappearing, which is more or less characteristic of the various types of osteosarcoma in contradistinction to other bone diseases.

As to differentiation it may be said that in aneurism the bone would show intact. Attention was called to the usefulness of the Roentgen rays in a case of femoral aneurism, which, on account of extremely thick walls, showed no pulsation, so that it had originally been taken for osteosarcoma, an amputation, then, having been considered. The femur appearing intact, it was evident that there was a disease of the soft tissues.

143. Osteoperiostitis.—In chronic osteoperiostitis the walls appear irregular, but the irregularity is one-sided and there is a globular or spindle-like shape. In tuberculosis the shade will be cloudy or shaggy. In osteomyelitis the cortex shows nearly normal outlines.

144. Syphilis.—The skiagraphic expression of syphilis is also characteristic. In the congenital form large ossified areas are recognized in the epiphyses that would appear translucent in their normal cartilaginous condition. On the other hand, light areas are noted in the diaphyses as an expression of insufficient calcareous deposition. The synchondrosis between the cartilaginous epiphyses and the diaphyseal end appears as a very marked line, indicating the abundance of calcareous salts deposited there. Gummata show regular light shaded foci. Their disappearance after the administration of iodid of potash confirms the diagnosis.

145. Osseous Cyst.—Osseous cyst, showing the same clinical signs as osteosarcoma, may easily be confounded with it. But in osseous cyst, while there is the same bulging as in osteosarcoma, the line of the cortex, on account of its thinness, appears narrow, but well marked and regular. The fluid center of osseous cyst renders the [illegible] transparent, the light shade showing the same [illegible] [illegible] adjacent epiphyses are also normal in appearance. The [illegible] of these various affections being different, the importance of a correct diagnosis is evident.

Osteomyelitis, necrosis, tuberculosis, syphilis, and osseous cyst demand conservative measures, while sarcoma calls for the most radical treatment.

The grave prognosis of sarcoma arms the surgeon against any feeling of sentimentality. Under such fatal circumstances he may not shrink from advising one of the most mutilating operations, because he knows that otherwise not only a limb, but also life will surely be lost.

On the other hand, how painful must it be for a surgeon to find that because of his error of diagnosis such radical steps have been taken unnecessarily; that, in other words, an extremity may have been amputated where only an osseous cyst existed, which could have been cured by simple incision.

It is indeed not very difficult to confound the two diseases. As emphasized in Art. **137**, osseous cysts resemble osteosarcoma in its slow, painless onset, often preceded by an injury; in the gradual bulging of the area involved; and in its preference for youthful age and the long bones. These being characteristic features of osteosarcoma, as well as of osseous cyst, it is evident that the differential diagnosis cannot be made by considering the history, nor by inspection, nor by palpation.

The fact that the interior of an osseous cyst is filled with opaque bloody serum and that its walls are lined with a smooth coat, while in osteosarcoma solid masses are formed, indicates that an exploratory incision combined with microscopical examination would clear the question of diagnosis.

But the Roentgen rays give us more valuable information than the exploratory incision itself, and for the patient a Roentgen ray exposure is certainly more agreeable than an exploratory incision. Should an operation be decided upon, the microscopic examination can then be made.

At the early stage, osseous cysts, be they at the tibia or at the femur, are easily overlooked, the symptoms being insignificant. Sometimes there is a very slight pain that comes and goes. The joints are freely movable, and neither inspection nor palpation reveals any abnormality. After several months have elapsed, the circumference of the extremity may appear very slightly enlarged, but it may not be before a fall on the thin shells of the cortex has produced a fracture that the symptoms are fully appreciated.

146. Osteoma.—Other osseous diseases, like osteoma, osteomalacia, and chondroma, also offer some skiagraphic peculiarities in proportion to their various textures. Osteoma, of course, shows the shape of the osseous deformity, but there is a normal architectonic structure.

147. Osteomalacia.—On account of the dissolution of the calcareous salts, osteomalacia is distinguished by the absence of an osseous shade. In contradistinction to osteosarcoma the whole bone appears translucent. In *chondroma* there is a regular light shaded area according to its cartilaginous character.

148. Acromegaly.—In acromegaly the phalanges of the head are broader than normal and show no osteophytes, while their epiphysial ends are thickened. The long bones appear straighter and broader than normal. Some of the carpal as well as of the tarsal bones are distinguished by the presence of exostoses.

149. In *myxedema* the epiphysial lines of the long bones show premature synosteosis.

150. In *syringomyelia* the epiphyses of the long bone are hypertrophied and show rich osseous proliferations, which, however, contain but few calcareous salts.

151. The changes in *rachitis* on account of the absence of calcareous deposits are characteristic. They resemble those of osteomalacia, from which rachitis is distinguished by the irregular arrangement of interspersed osseous structures as well as by the deformed shape of the bones.

152. In *cretinism* similar conditions are found, the epiphyses being nearly invisible while the diaphyses only show distinctly.

153. Raynaud's Disease.—A peculiar condition of the bones was discovered in Raynaud's disease. A woman of 40 years, who had been well until 14 years ago, noticed a slight pain in the index finger of the left hand. At the same time she noticed a marked pallor of the whole finger. Four months after the sudden onset of the pain repeated congestion was observed in the region of the second and third phalanges of the same finger, which continued until about 6 months after the onset of the first symptoms, the tip of the finger becoming dry and black. Amputation was then performed. The patient regained and kept her health until 6 months ago, when the same pain and pallor extended symmetrically over both hands.

When the patient was seen for the first time a great pallor of the third, fourth, and fifth fingers of the left hand and of the little finger of the right hand was noticed. The second, third, and fourth right-hand fingers were moderately anemic. Sometimes the color changed into a cyanosed appearance.

Both hands were very cold, just like true gangrene. No other parts of the body were affected. There was no fever. The examination of the urine was negative. The patient did not seem to be hysterical, but apparently suffered intense pain sometimes.

The skiagraph showed atrophy of the upper end of the third phalanges (second phalanges of the thumbs) and osseous proliferation at the upper end of all second phalanges (first of thumbs). The third phalanges appeared triangular and resembled claws.

A similar condition was found in a feeble man, age 30 years, who, at the present time, has fully recovered. The onset took place in the toes of his right foot, gangrene of the whole foot becoming complete 2 months afterwards, so that Syme's amputation was performed. Skiagraphs taken of the foot before and after operation showed nothing abnormal. But 1 year later the disease commenced in both hands to a moderate degree. The fingers were covered with cold sweat and red and blue patches sometimes. The tip of the left index finger together with the upper end of the third phalanx became gangrenous. The patient was treated with arsenic and local gentle massage. The nutrition of the bone is much more disturbed by this sphynx-like vasomotor lesion, than is assumed. It would be

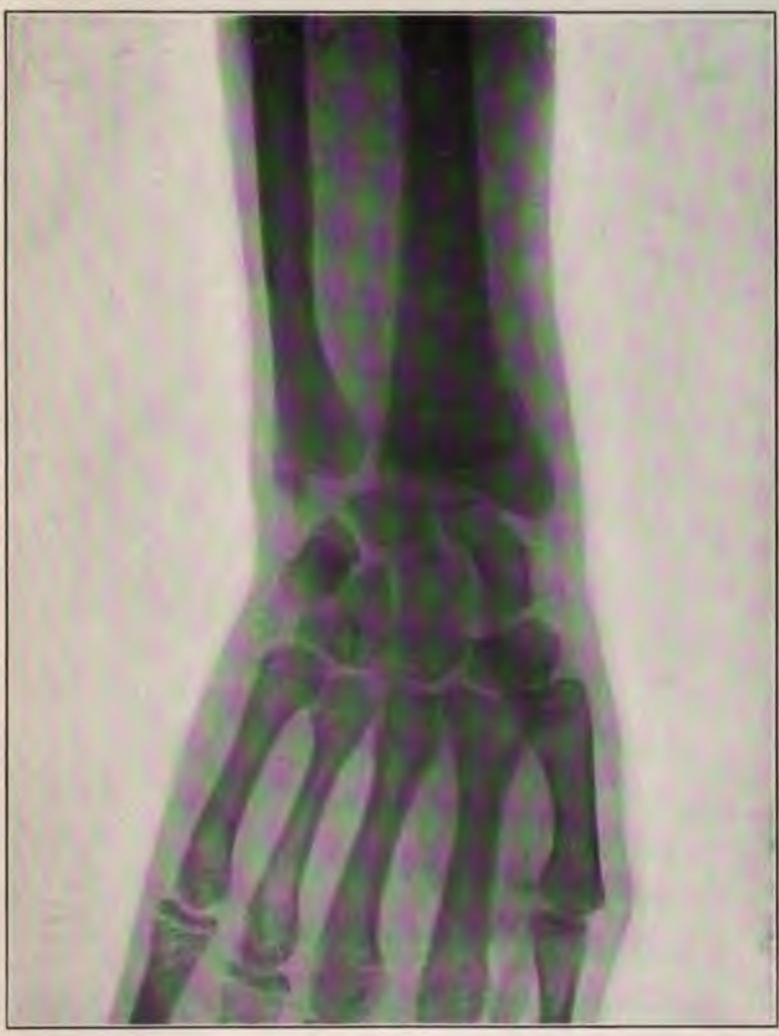

PLATE XXXIV.

Osteoepiphysial Separation of Carpal End of Radius.

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well worth while to study these phenomena more extensively. The skiagraphic characteristics described, however, are not expected to serve as substitutes for our well-tested clinical methods of diagnosis, but should be regarded as a valuable adjunct in general, and sometimes as a determining factor in doubtful cases.

THERAPEUTIC VALUE OF ROENTGEN RAYS.*

154. Soon after the utilization of Roentgen's discovery reports of extensive dermatitis and gangrene of the integument were published, which disturbed the public mind in a deplorable and unjustifiable manner. But, especially since the time of exposure is now so much shorter than during the earlier stages of the art, the possibility of originating skin irritation is extremely small.

It is undeniable that a peculiar trophoneurotic idiosyncrasy exists in a few individuals, but in the great majority of known cases the burns of the skin were caused by the lack of knowledge of the unskilful operator, the tube often being too near the subject, or by too prolonged and too often repeated exposures. Such accidents are not surprising, so long as laymen, such as opticians and instrument makers, who understand nothing of the anatomy and physiology of the skin, are entrusted with the "manufacture of skiagraphs."

155. The question of proper dosage must be perfectly understood by the operator. A person, for instance, that irradiates a patient suffering from some skin affection every day intensely for a whole hour, irrespective of the reaction following such a radical procedure, so that gangrene occurs, has just as little business to do skiagraphic work as a shoemaker has to prescribe morphin.

Since February, 1896, we have made nearly 4,000 skiagraphs, and have never observed the slightest irritation of the skin in any case in which the rays were used for diagnostic

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*See also Therapeutics of Roentgen Rays in *Electricity in Surgery.*

purposes, except lately when we experimented with very powerful tubes. A very stout man, who after having suffered from pyothorax for more than 2 years and who still presented an open cavity, was irradiated for the purpose of determining the extent of rib-resection performed previously. The pleuræ had become very much thickened, which explained the difficulty of penetration. Nine exposures had to be made in short succession until a satisfactory plate was obtained. One week after the last exposure dermatitis of the irradiated area set in, from which the patient did not seem to suffer much. In fact, he took the itching sensation felt as one of the many annoyances of regular wound treatment. The therapy consisted in the application of boro-salicylic solution during the acute stage, which lasted 5 days. When the epidermis began to peal off, dermatol was dusted on the surface. Recovery was perfect after 3 weeks. The scar is still noticeable, after 3 months.

With the ordinary tubes two cases of circumscribed depilation were observed. In both patients the skull had to be skiagraphed frequently and at short intervals. In one case depilation began after the fifth, and the other after the sixth, exposure, and in both instances the hair was perfectly restored 3 weeks afterwards.

Changes in the pigmentation of the integument or in the growth of the finger nails, congestion, inflammation, and necrosis of the skin are reported. While experimenting with the powerful tubes, which were responsible for the dermatitis described, we observed cessation of perspiration on the dorsal surfaces of our hands, so that we had to stop work entirely for several weeks, when normal conditions were restored again.

To protect the operator it has been advised to use the patient's hands for ascertaining what degree of translucency is shown by the tube. But while this is no doubt the simplest way of self-protection, it is not in accord with the principles and the spirit of the noblest of all professions.

We have suggested the wearing of gloves lined with tin-foil during examination, the hands to be used alternately for ascertaining the degree of translucency. The fluoroscope recently devised by Levy-Dorn also protects the hands of the operator to some extent and can be recommended for that purpose.

Excessive irradiation endangers the hand of the operator. One of the most promising German investigators burned his hands to such an extent that, first, amputation of the index finger and, later on, of the arm was necessary. The victim of science being of poor health at the time, his death from the shock of the operation is explained easily.

156. It was not more than natural that these properties of the rays were soon utilized for therapeutic purposes. Cases of hypertrichosis, or nævus vasculosus, of all the various types of eczema, psoriasis, and sycosis, have been reported as cured by the rays. There can also be no doubt that parasitic skin diseases such as lupus vulgaris and erythema yield to the rays. Sycosis parasitica as well as non-parasitica and favus have been cured after one exposure.

In a case of sycosis parasitica that had existed for 6 years and had resisted the usual methods of treatment, a perfect cure was obtained after an exposure that lasted 7 minutes only.

In a case of lupus of the inguinal region, a perfect result was obtained. After the sixth exposure, inflammation of the lupus area began and the nodules shelled out, together with the destroyed tissue. In their place a light red ulcus remained that bled at the slightest touch and which did not cicatrize until 9 months after the last exposure. In such cases transplantation is generally indicated. It goes without saying that this mode of treatment, while most effective, is very annoying to the patient, whose gratitude to the physician is somewhat restricted on that account, even after perfect recovery.

In some of the cases reported the nodules did not shell out, but shrank, presenting the appearance of having been painted with varnish.

157. A great deal, however, can be done to limit the ill consequences of the irradiation treatment of skin diseases, which should not be resorted to unless all other therapeutic measures have been exhausted. Under proper precautions the ill effects of the rays can be avoided. In the first place, the healthy parts in the vicinity of the diseased area should be protected by sheets of tin-foil. Then the patient's subjective condition should be carefully watched. As soon as there is a slight burning sensation or itching within the irradiated sphere, further exposures must be stopped.

158. For therapeutic purposes the tube should be as near the diseased area as possible, and the time of the first exposure should not be longer than 10 minutes. Later on, if no reaction occurs, the irradiation may be kept up for from 20 to 30 minutes. In lupus, as many as fifty exposures may be necessary to destroy the nodules. In obstinate cases exposures may be made daily.

During the intervals the diseased area should be powdered with amylin or dermatol. In the event of relapse, the same treatment must be commenced again.

It is necessary to individualize, just as in other therapeutic indications. Some individuals show signs of irritation after a few exposures, and others do not react until after frequently repeated and intense irradiations.

At first these remarkable results were explained on the theory of bactericidal influence of the rays. But it seems that their effect is of a decidedly electrochemical character, the congestion caused by the irradiation being mainly responsible, just like the artificial hyperemia in tuberculosis. In disturbed nutrition of the skin the inflammatory reaction produced by the rays sets up an alteration in the circulation of the affected spheres.

159. Bacteriologic experiments have shown that the rays, applied directly after inoculation with anthrax bacilli as well as with streptococci and staphlococci, had no effect. But pure cultures of cholera, typhus, and diphtheria died after an exposure of 48 minutes to intense radiation. It seems that various bacteria react differently, according to the quality of the plasma and the degree of the fluid they contain.

160. The good results obtained recently in the treatment of epithelioma induced us to try irradiation in sarcoma. The patient, a strongly built cooper of 36 years, remembers that

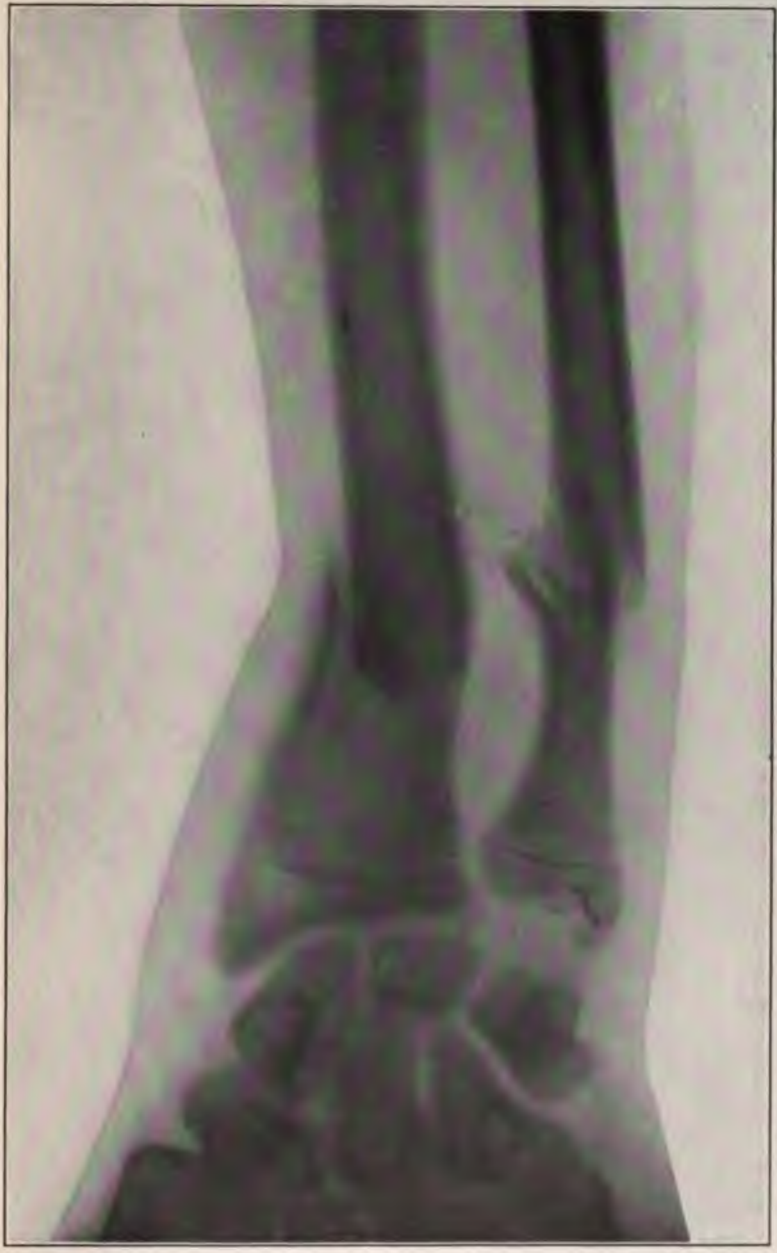

PLATE XXXV.

Fracture of the Lower End of the Radius Combined With Fracture of the Ulna, Showing Deformed Union.

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ever since 15 years he observed a small black speck (mole?) at the region of his external malleolus. About 1 year ago it assumed the appearance of a common verruca. A continuous increase in size was observed then. In November, 1900, the "verruca" became sensitive and the surface began to excoriate. Carbolic acid baths were now prescribed by the patient himself and faithfully used, until about Christmas the growth had reached the size of an apple. It was not until then that the patient became afraid and consulted his family physician, who referred him to the St. Mark's Hospital.

On December 24, 1900, he was found in the following condition: The strongly built patient showed a healthy appearance. He admitted being a potator. The family history was good. At the region of his left external malleolus a tumor of the size of an apple was noticeable. Its consistency was moderately hard, its surface of a smoky gray color, and seemed to have originated from the confluence of a number of small warts. It could not be dislodged from its base. The inguinal region contained a gland of the size of a walnut.

At first the diagnosis lymphosarcoma was made and amputation was proposed, but the patient refused to submit to it. His family also being adverse to such radical steps, we contented ourselves with extirpation of the tumor and of the inguinal gland. The apparently healthy periosteum of the externe malleolus was removed together with the neoplasm. Recovery being perfect in a few days, the patient left the hospital.

Microscopical examination of the growth revealed the presence of pigment that proved that we had to deal with melanosarcoma, the most malignant type of sarcoma. The patient returned to the hospital 6 weeks afterwards. The same tumor showed at the outer malleolus again, but it was somewhat broader and flattened. Its margin was encircled by a few bluish-black nodules of the size of a pea, which could be compared with hemorrhoidal nodules. A glandular convolution of the size of a goose egg had developed in the inguinal region in the meanwhile. Extirpation was performed again. The patient withdrew from treatment 2 weeks afterwards, his excuse being that he felt perfectly well again. Four weeks thereafter he presented himself again with a relapse. This time there were about 30 dark bluish-black grape-like nodules of various sizes. The larger nodules bled easily on touch. The inguinal region showed a tumor of the size of the head of a new born child. At the inner surface of the leg, especially alongside the inner border line of the calf, several dozens of nodules had originated that closely resembled those of the tumor itself. Their size varied between that of a head of a pin and a cherry. Extirpation was done once more. The microscopical examination of the removed portions showed the alveolar character and deposits of pigment in the large cell-nests as well as in the small cells of the supporting tissue. One of the specimens was colorized with hematoxylin and esin and a second with van Giesons' fluid.

The patient would not have submitted to amputation, but regarding the metastasis in the inguinal region, the prospects of such an operation at this late stage would not have been promising. Serum-treatment was now considered first. Although we had never experienced any benefit in a fairly large number of malignant cases, still we regarded its use justifiable in such desperate cases. But at the same time the thought of Roentgentherapy suggested itself to us. The excellent results obtained in lupus and other skin affections by Albers-Schoenberg, Hahn, Schiff, Freund, Ziemasen, Kümmell, Muehsam, Holland, Schenkel, Jutassy, and Neisser, could also be corroborated by us (see Irrtuemer der Roentgenographie, Deutsche Medicinalzeitung, 600, No. 51, and Fractures, With an Appendix on the Practical Use of the Roentgen Rays, Philadelphia, 1900). In epithelioma of the lower eyelid and of the cheek we obtained a perfect result after a few exposures only. Without entertaining audacious hopes we began to irradiate the defect left after the last extirpation. The time of exposure was at first 10, then 20 and 30, and at last 45 minutes. When the exposure lasted 45 minutes the patient felt an itching sensation over the whole leg, which lasted for several hours. Irradiation was done 7 times. At the end of 6 weeks not only was there no trace of a relapse, but a number of the metastatic nodules of the calf, especially those near the area of the irradiation, had disappeared; some others had shrunk.

The inguinal tumor became larger during the time of this treatment. It is our intention to remove it again and to irradiate the wound area left as soon as there is a possibility.

As mentioned before we are far from indulging in adventurous hopes. But such experiments are justifiable in so desperate a case, even if they should be without any result. But the fact cannot be denied that in great contrast to the former course after preceding extirpations, no relapse was observed, and what is still more interesting, well developed sarcomatous tissue shrank and *cicatrized*. This proves the influence of the rays beyond doubt. How far this influence goes, however, is not demonstrated by this observation and further experiments have to clear that up.

161. We venture to call attention to the fact that since Heidenhain proved the existence of carcinoma cells below the fascia in carcinoma mammæ, surgery has drawn the practical conclusion that the pectoralis major muscle—or at least its superficial stratum—must be removed, since no surgeon at the present time would expect recovery from the mere extirpation of those cancerous portions that are microscopically visible.

If the carcinoma cells have advanced so far that they have ceased to be accessible to the scalpel, speedy relapse can surely be expected. Now, if we had a means that would, after thorough removal, penetrate the deeper strata so that those carcinoma cells that are situated beyond the reach of the knife would still be attacked by it, and perhaps destroyed, or at least arrested in their further development, the question of the therapy of cancer would be solved.

If the parasitic nature of carcinoma will be proved some day, the effect of an antiparasitic medium can be easily understood. The Roentgen rays possess antiparasitic properties to a certain extent. Their therapeutic significance is still sphynx-like. But it can safely be maintained that their effect is sui generis and cannot be compared with that of Paquelin's cautery or of the obligate mustard plaster.

These views may, it seems to us, be applied to the sarcoma question. The danger of burning the patient is not small under such powerful treatment. While experimenting, other parts of the body must be protected with tin-foil and the operator himself should wear gloves lined with tin-foil. The danger of Roentgen ray dermatitis, however, should not have great weight in a malignant case. For the poor therapeutic results reported by some investigators the fear of using a strong current may be held responsible. If a strong effect is desired, intense irradiation must naturally be used. The patient, of course, should be informed about the risk.

In revising this report 3 weeks after the demonstration, the defect at the outer aspect of the malleolus was perfectly cicatrized. After 9 weeks no relapse had been observed. The inguinal tumor was removed on the day after the demonstration, as intended, and now the inguinal area is also irradiated. The disease had reached a stage in which final recovery can hardly be expected, and it is to be regretted that the thought of Roentgentherapy did not suggest itself at an earlier period. Further reports on the fate of the patient are reserved.

FALSE INTERPRETATIONS OF THE ROENTGEN RAYS.

ITS MEDICOLEGAL ASPECTS.

162. The ease with which some of the small bones of the human body can be reproduced by the rays on a photographic plate led many medical novices, and even laymen, to the indiscriminate use, or rather abuse, of the new discovery. It is little wonder that the results of such an abuse of the rays were soon heralded and misapplied by officious friends, inconsiderate confrères, and last, but not least, by certain members of the legal profession.

In order to avoid errors, it should never be forgotten that a so-called Roentgen ray picture is by no means an ordinary photograph of an object, but only a silhouette (skiagraph),

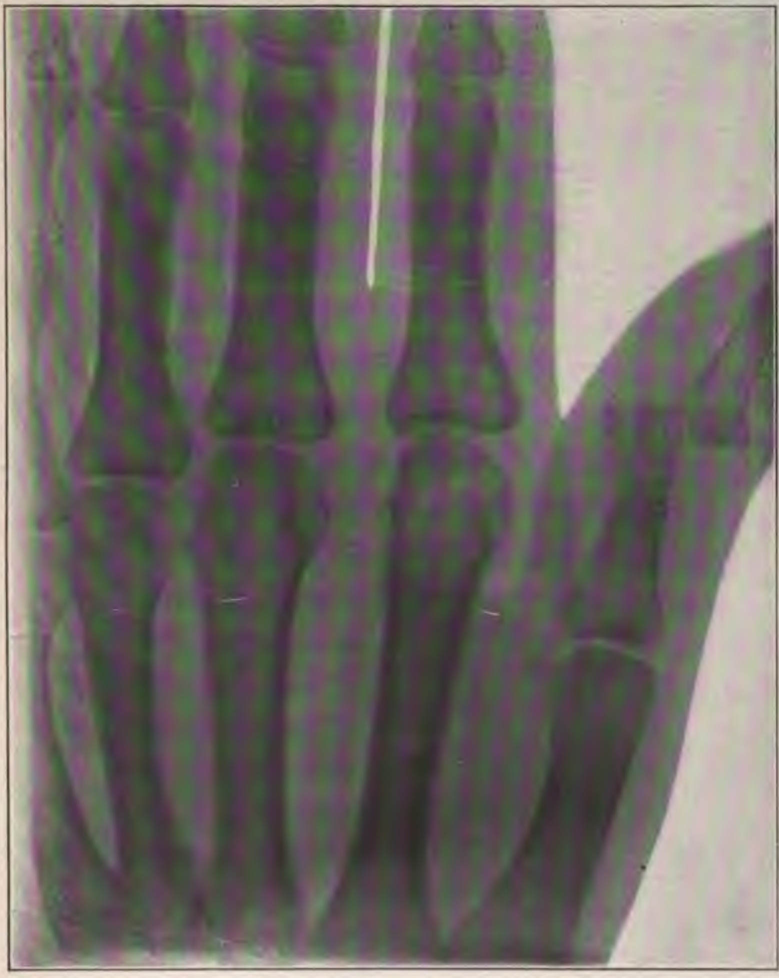

PLATE XXXVI.

Dorsal Dislocation of Thumb.

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that is, a photograph of its shadow. To interpret such shadows properly, a thorough knowledge is required of the normal anatomical relations of the tissues, especially of the bones that produce such shadows. As the most minute gradation of density is registered, it is important to be thoroughly acquainted with the anatomical relations of the bones producing the doubtful shadow. The question, then, will be whether the supposed shadow is normal or not. On certain portions of the skeleton the muscles and tendons will naturally cause obscure shadows. The carpus is especially prone to produce such errors in the skiagraph; the tuberosities of the trapezium, the scaphoid, the hamulus ossis hamati, the os pisiforme, and the eminentiæ carpi volaris, radialis, and ulnaris double up the thickness of the carpus, thereby causing dark shadows that might be mistaken for foreign bodies. Similar considerations and similar cautions apply to other diagnostic opportunities offered by the rays.

163. Projection Plane.—If a skiagraph of the human hand, for instance, is taken, the plate will show the least light where the bones rest, while the soft tissues appear opaque. There is also a difference of opacity according to the thickness of the tissues, their blood-supply, and their air capacity. The foot, while easily skiagraphed in the direction of the dorsum toward the planta pedis, from the toes to the upper third of the metatarsus, presents an obstacle farther backward in the first and third cuneiform bones and the scaphoid, so that it is necessary, also, to skiagraph the foot on these portions transversely by having the outer surface rest on the support. It is by this procedure only that the isolated shadows of the astragalus, the calcaneum, the os cuboidum, the scaphoid, and the fourth and fifth metatarsal bones can be distinctly outlined, so that false interpretations may be excluded. In the early era of the Roentgen rays, the normal sesamoids were, also, sometimes incorrectly interpreted.

How important the knowledge of minute anatomic details is, especially of non-pathological abnormalities, will be evident from the fact that the os intermedium cruris (os trigonum tarsi) has been mistaken for a fragment severed from the astragalus.

164. It should also be borne in mind that the significance of a skiagraph for the purpose of estimating the *degree of functional disability* is not always conclusive. A skiagraph may show a considerable degree of bony deformity after a fracture, and still the function may hardly be disturbed. Skiagraphic test has shown that, as a whole, even our best functional results do not always show ideal union. An unscrupulous patient that secures possession of a skiagraph of his own case, which shows considerable deformity, may, although there is no functional disturbance, strongly appeal to a jury on the strength of his skiagraph, if he succeeds in simulating great impairment. On the other hand, there may be but little evidence of bone injury on the skiagraph, but there may be severe impairment of function on account of the injury of the soft tissues (circulatory, trophic, or inflammatory disturbances) that can be represented only faintly, if at all. This shows the necessity of considering all the clinical symptoms in connection with the skiagraph.

165. While it is easy even for a layman to understand the significance of most skiagraphs, there are, as has been mentioned, injuries, the correct interpretation of which presupposes, besides thorough anatomic knowledge, the greatest care and a vast amount of experience as to the different modes of delineation in various projection planes.

The greatest diagnostic difficulties are offered by the joints. The more complicated the joint is, the more complicated, naturally, will the skiagraphs of its various positions appear. It is especially the elbow-joint and hip-joint that are kept in view. First of all, the interpretation of the displacement caused by supracondylar fracture of the humerus and the deformities resulting from it later on may tax the power of discrimination considerably. The older the fracture, the less conspicuous the fracture line will appear. In old fractures the lines cannot be represented as such, and it is only in the case of a union in a displaced position that its features can be guessed. In the case of a woman, age 70 years, for instance, a second skiagraph taken 5 years after a supramalleolar fracture was sustained showed essentially the same features as the first, which had been taken 4 weeks after the injury, because of the marked displacement of the fragments.

166. In case of the entire absence of displacement, it is only a very distinct skiagraph that shows the line clearly. It is natural that in such cases there is no skiagraphic evidence after recovery—that is, in 4 to 10 weeks, according to the type of the fracture. Should a court, for instance, doubt, in such an event, that there had been a fracture, the skiagraph taken after such a period might show a negative result, although there surely was a fracture. In some cases, as stated before, a very distinct skiagraph, taken only 2 months after a well-proved fracture, showed no signs of it. Had such a case not been skiagraphed shortly after the injury no evidence of the fracture could have been subsequently obtained. When no displacement exists, only a faint fracture line will show, but the presence even of a small amount of callus leaves no doubt as to the previous existence of a fracture.

On the other hand, callus formation may under extraordinary circumstances be so abundant that, in spite of the absence of displacement, the fullest evidence of fracture may still be furnished after months have elapsed. In one case callus formation was so excessive that the attending physician was accused of malpractice, and it was only the skiagraph that convinced the patient that his physician had treated him correctly, the bones being in perfect apposition, and thus exonerated the practitioner.

167. The intra-articular type of fracture offers the greatest diagnostic difficulties, inasmuch as the fracture line is often obscured by the callus formation. If, however, a skiagraph of the other joint is made at the same time, in the same position, and in the same projection, the various delineations of the shadows will be correctly understood and interpreted.

168. A normal skeleton should also be compared with the skiagraph. It should be particularly remembered that certain pathologic conditions, such as rachitis, for instance, influence the outlines of the bones and may deceptively be supposed to represent a portion of the injury. In such an event a skiagraph of the fellow extremity will set matters right. In very young children the eminentia capitata appears as if entirely severed from the humerus, although the relations are absolutely normal. The explanation of this very important phenomenon is that the epiphysial tissues are not sufficiently ossified to produce a shadow on the plate. If these points are not thoroughly considered a displaced fragment of a fracture might cause an erroneous diagnosis. Union between the epiphysis and diaphysis of the head of the humerus is not perfect before the twentieth year. The lower epiphysis of the humerus consists of four nuclei that ossify between the eighth and seventeenth years. The epiphysis of the trochlea as well as of the olecranon ossify between the seventh and twelfth years, which explains why an osseous nucleus that is still connected with its neighboring epiphysial nuclei and the diaphysis by cartilaginous tissue appears as an isolated piece of bone which might erroneously be mistaken for a fragment. The acromioclavicular junction sometimes shows in the skiagraph a hiatus of the width of a finger so that a diastasis of the joint may be assumed (see Plate XXVI). But since our knowledge of this new subject has increased, we know that this apparent diastasis is by no means pathological and that there is a normal gap between the osseous ends of the acromion and the acromial end of the clavicle. The upper epiphysis and the diaphysis of the radius unite between the seventeenth and the eighteenth year. During the early work with Roentgen rays the translucent space above the epiphysial cartilage in children was erroneously taken for a fracture line. The head of the femur unites with the diaphysis at the eighteenth year, and the lower epiphysis follows after the twentieth year. The upper epiphysis of the tibia unites with the diaphysis in the twentieth or twenty-second year, while the lower tibial epiphysis unites with the diaphysis between the eighteenth and nineteenth years.

169. For the thorough interpretation of skiagraphs in children, it is important to know that at birth the diaphyses

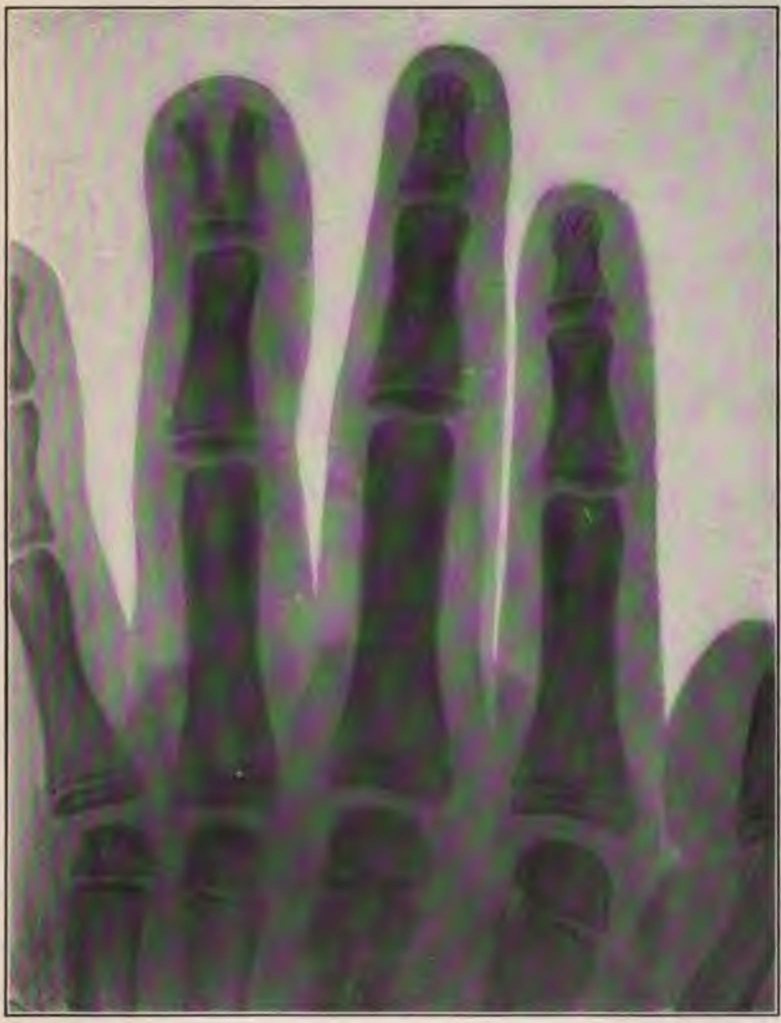

PLATE XXXVII.

Longitudinal Fracture of Third Phalanx of Ring Finger.

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of the radius and ulna are ossified, while their epiphyses as well as the whole carpus are still cartilaginous. It is not before the seventh year that an osseous nucleus shows at the lower epiphysis of the ulna. Union with the diaphysis sometimes begins with the twelfth year, but as a rule not before the fifteenth. Even then a small epiphysial disk remains, which does not disappear before the seventeenth year in the female and not before the nineteenth year in the male.

The osseous nuclei of the carpus show at different periods, viz., at the os capitatum at the fourth month; at the hamatum at the fifth month; while the triquetrum shows its nucleus between the second and third years, the lunatum between the third and fifth, the naviculare between the fifth and the seventh, the trapezium and the trapezoid between the eleventh and the fifteenth year. After 5 years the capitatum, hamatum, and triquetrum have assumed their regular shapes, while the others, with the exception of the pisiform, are perfectly developed at the twelfth year.

The osseous nuclei of the epiphyses of the metacarpal bones show at the second year, their synosteosis with the diaphysis taking place between the twelfth and seventeenth years in the female and at the age of nineteen in the male. The epiphysial nuclei of the phalanges are ossified between the fourth and fifth years, their synosteosis with the diaphysis taking place at the same age as that of the metacarpal bones (from the twelfth to the seventeenth year in the female and between the sixteenth and nineteenth years in the male).

170. Regarding the elbow-joint, it must be considered that an osseous nucleus appears at the medial side of the capitulum humeri between the second and third years, another one in the internal epicondyle at the fifth year, a third in the trochlea between the eleventh and the twelfth year, and soon afterwards a fourth in the external epicondyle. The nucleus of the internal epicondyle unites with the diaphysis between the sixteenth and the twentieth year; but the other three nuclei form a synosteosis among themselves at the seventeenth year and then form the uniform osseous epiphysis, which completes its synosteosis with the diaphysis at about the twentieth year. In the capitulum radii an osseous nucleus appears between the fifth and seventh years, and in the olecranon between the sixth and eighth years, both uniting with the diaphysis between the twentieth and twenty-fifth and between the sixteenth and twentieth years.

171. Regarding the knee-joint, it must be considered that the lower femoral epiphysis contains an osseous nucleus at birth, while the nucleus in the tibial epiphysis shows shortly afterwards. At the fourth year both these epiphyses have completed their development, but they do not unite with the diaphysis before the fifteenth year. Textbooks on anatomy say that union takes place between the seventeenth and the twenty-fourth year, but skiagraphic experience points to an average period of only sixteen. The osseous epiphysial nucleus of the fibula appears between the second and the fifth year and unites with the diaphysis between the eighteenth and the twenty-fifth year; but skiagraphy dates this period earlier, viz., the fifteenth year. The osseous nucleus in the tibial spine appears between the eighth and the tenth year; the epiphysial line between it and the diaphysis disappears at the fifteenth year.

172. As to the bones of the foot, it may be said that the lower epiphyses of the tibia and fibula show their osseous nuclei in the first and second years and unite with the diaphysis between the eighteenth and the twenty-fifth year; according to skiagraphs, as early as before the eighteenth year. The osseous nucleus of the astragalus and calcaneum appears in utero, that of the cuboid shortly before or after birth, that of the cuneiform bones between the first and the fifth year, and that of the os naviculare from the first to the fifth year. The osseous nuclei of the metatarsal bones and of the diaphysis between the sixteenth and the twenty-second year.

173. In elbow-joint fractures occurring in childhood it is necessary therefore to take at least two skiagraphs in different projection planes and to compare them thoroughly with the normal fellow. In a case of a fracture of the femoral head, for instance, the deformity had appeared three times as large as it actually was, on account of inappropriate projection. The degree of shortening of the limb was overestimated accordingly. This shows the necessity of considering the clinical symptoms and data in connection with the skiagraph.

In fractures of childhood it should also be remembered that the process of ossification is influenced by various affections of the bone, as for instance, by rickets.

174. The importance of the question of projection becomes evident when we consider that grave errors may sometimes occur even if all preliminary conditions required for a thorough understanding of the case seem to be fulfilled. This will appear from the experience given of the fracture of the tibia, Art. **84.** If that case had been brought before a jury the expert might there, on the strength of the first skiagraph, have testified in good faith that there was no fracture.

As emphasized previously, this experience teaches the necessity of adopting the principle of always taking at least two skiagraphs in two different positions in all cases of suspected fracture.

175. In taking skiagraphs of foreign bodies it must be considered that their size varies according to the distance from the tube. In oblong bodies great errors as to their extent may be committed. Once we were very much surprised in a case where a fragment of a needle had entered the palm of the hand in a perpendicular direction. The plate, while indicating the presence of the needle, distinctly created the impression that the fragment was only about 2 millimeters in length. When extracted it was found to be more than an inch long, the rays having reached the hand in a perpendicular direction so that the circumference of the fragment was reproduced rather than its length. A side view, of course, would have cleared up the error at once.

176. Misinterpretations have also arisen from unavoidable mechanical and chemical defects causing markings in the photographic plate, the significance of which must be well known to the skiagraphic interpreter. Blemishes may also be produced by spots caused by pus from wounds or by perspiration.

In the location of foreign bodies, especially in the skull, many errors were and are still committed.

For malingerers the Roentgen rays may prove to be, for a time, a protection on account of erroneous interpretation, but they will be shown in their true light when assisted by better anatomical knowledge.

177. Soon after the discovery of the Roentgen rays the courts were in a position to grant damages to patients, especially veteran soldiers, who claimed to have been damaged by bullets and were unjustly rejected by medical experts as malingerers. The presence of a bullet, shown on the photographic plate, cannot be denied, and a patient that harbors a piece of cold metal in any part of his body has, as a rule, a good reason to complain. On the other hand, an impostor who pretends to have been shot and simulates functional disability will be exposed by a distinct skiagraph, which would show the absence of the alleged bullet.

It is still an open question whether the court has a right to censure a surgeon for not having used the Roentgen rays in a suitable case, and, furthermore, whether it can compel a patient in a doubtful bullet or fracture case to submit to an exposure by the rays.

178. A distinct skiagraphic plate will always tell the truth. If accompanied by registration of the details of operation, viz., the source of the current (whether battery, static-machine, or street), the length of spark of the induction-coil, the intensity of the tube, the distance of the platinum disk of the tube from the photographic plate, the position of the object, the kind of plates, and the time of exposure, it will be a valid document intelligible to every expert. And together with the anatomic and clinical knowledge of the expert it should be evidence in court.

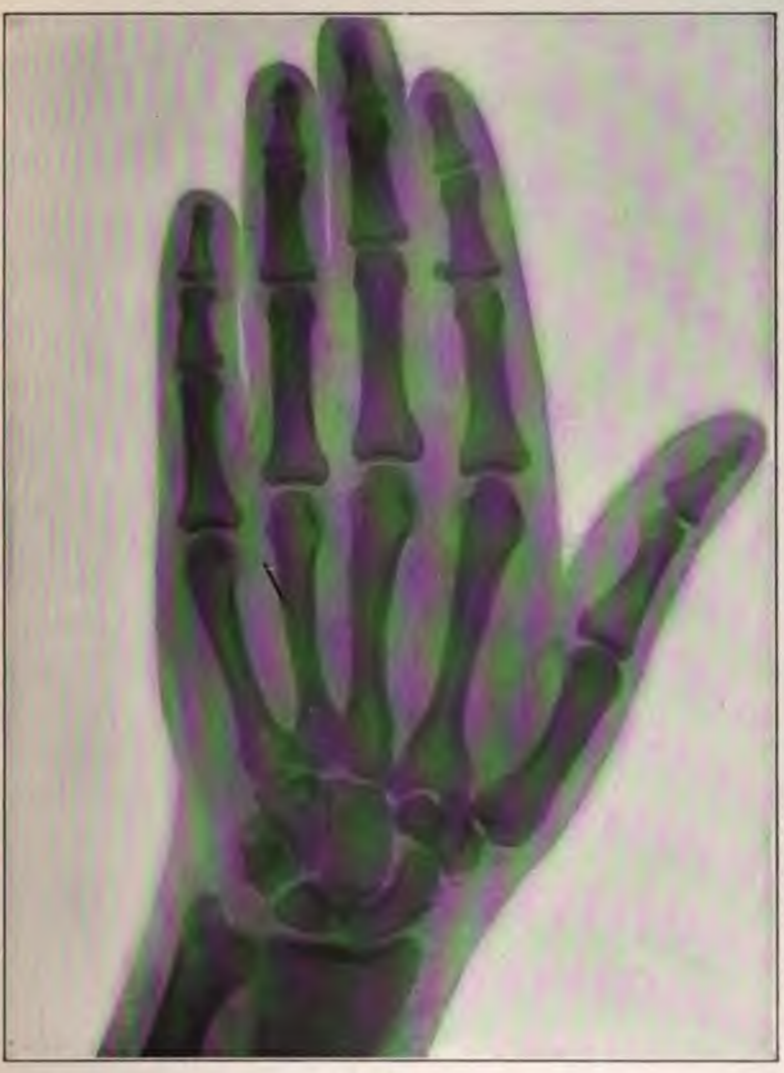

PLATE XXXVIII.

Needle, Showing its Eye, in the Palm of the Hand.

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ROENTGEN RAYS IN DENTISTRY.

(EXTRACT FROM *Electricity in Dentistry*, BY LEVITT E. CUSTER, B. S., D. D. S.)

179. The Roentgen rays have no more fitting application than in dentistry. In medicine and surgery their use as an aid in locating foreign bodies has never been questioned, in diagnosing fractures and dislocations, and in detecting the presence of calculi and pus cavities and even the abnormalities of some of the softer tissues whose density differs but little from that with which they are surrounded. The Roentgen rays are also of value in some of the arts, and as the appliances are being perfected and new uses are found for it, its applications are still broadening. The most valuable field, however, will always be in medicine, surgery, and dentistry.

180. While the use of the Roentgen rays in dentistry is not usually in cases in which it is a matter of life and death, as is frequently the case in surgery, its more frequent use will give it a value of a high order. Its dental applications, while confined to a comparatively small portion of the body, are of rather wide range and will require just as much skill on the part of the operator as in work on the thicker tissues. For instance, the dentist must be able to so manipulate his tube and appliance as to differentiate between the roots of the teeth and the bone that surrounds them, a feat equal to any accomplished by the physician. Or, on the other hand, he may have simply the location of a broken broach or a pus cavity, which is comparatively easy. The most frequent dental uses of the Roentgen rays are for locating unerupted teeth, for ascertaining their position and the shape of their roots, for diagnosing fractures of the jaw, for locating foreign objects such as a broken broach, for determining the depth of root filling, the extent of an abscess, or the proportions of the antrum.

181. The successful use of the Roentgen rays requires a somewhat formidable array of appliances, and the manipulation of them calls for one that is accustomed to mechanical details. To this extent the dentist is very well fitted at the very outset by the nature of his mechanical and digital acquirements.

Instruments and instrumentation are his daily company and his occupation. Moreover, Roentgen ray work being an electric process, the majority of dentists are to a large extent familiar with the fundamental electrical requirements and are already equipped with many appliances that may be used in the work. All things being considered, at the present state of perfection of Roentgen ray appliances, the dentist will obtain the most satisfactory results from the Rhumkorff coil. It is also recommended that he procure one large enough for general work. The city dentist, who is in touch with the general physician or with some established Roentgen ray laboratory, will be most practically profited by the use of an 8-inch or 10-inch coil; but if he expects to derive the most pleasure and benefit from the work he should get a 12-inch or 15-inch coil, for then he will be able to manage all parts of the body. For the country dentist the larger coil is especially recommended, for the reason that the electrical part of his dental office appliances will already form a large part of his equipment, and many physicians will prefer to avail themselves of its use than to take up the work themselves.

182. It is customary in taking a skiagraph to use a plate for large subjects and a film for the smaller. For dental operations the film has especial advantages—it is cheap, convenient to handle, easy to prepare, and is flexible. A cartridge of a 1½-inch film, such as is used in the Brownie camera, will be found to be the most economical, and this can be had at all photographic supply houses. The width of this film is the most convenient; the average dental case can be taken upon a square cut from the end, and if the case calls for a larger piece, it is only necessary to cut off an oblong piece sufficient for the case and place the strip lengthwise.

The plates to be used for larger subjects may be found upon the market. When necessary, ordinary photographic plates may be used for Roentgen ray work with splendid results, but plates especially prepared for Roentgen ray pictures, such as the Cramer or the Carbutt, are to be found. These plates are supplied either in or with light-proof envelopes. We have found that the Cramer Crown brand of plates gives the best results, almost as good as those plates that are especially prepared for Roentgen ray work.

183. The next step is the providing of a light-proof and, to a certain extent, moisture-proof covering for the film. If the dentist has a good coil and becomes expert in the management of his appliance, he will require but a few seconds for an exposure, and his film may be enclosed in two thicknesses of black paper without danger of light or moisture. The film is placed sensitive side down upon a piece of paper 3″ × 4″, and the edges are turned over upon the back of the film. This is then placed upon another piece of paper somewhat larger than the first and enclosed in the same manner. A little gum paper will prevent the opening of the flaps. The film, thus enclosed, is flexible and neat, and can be easily adapted to any part of the mouth.

184. If the dentist requires a considerable length of time for an exposure, he may enclose his film in black unvulcanized rubber, as suggested by Doctors Van Woert and Price. The film should first be covered with an envelope of tissue paper to prevent adhesion of the rubber to the film and also any injurious effects of the rubber upon the film. The black rubber being quite flexible and adhesive, a piece is cut twice as large as the film. The film is placed upon one half and the other half is turned over upon it and the edges pinched together. This makes a light-proof and moisture-proof covering, and a film protected in this manner may be immersed in the saliva without danger of injury therefrom.

185. Dr. C. E. Kells has suggested the use of a little plate holder. This is made by first taking a modelling compound impression of the coronal and lingual aspect of the teeth to be skiagraphed. A piece of 28-gauge aluminum is attached to the inner side of the compound, and to this the piece of film, protected as previously described, is attached by little clips. The whole is then placed upon the teeth and the patient instructed to close the mouth. There are two advantages in this method. It leaves the operator free to manipulate the instrument and the film can be held more quietly. This method is especially valuable where, by the nature of things, from 30 to 90 seconds are required for a dental skiagraph, but when a large and efficient coil and tube are used and but from 3 to 10 seconds are necessary, the film can be held quiet for that length of time by the assistant.

186. The film having been prepared, the patient is comfortably seated in an ordinary chair with a portable head-rest upon the back. An ordinary chair will be found most convenient for the reason that in taking skiagraphs of the upper jaw it is necessary to place the tube well above the patient to have the rays strike the plate perpendicularly and to get the teeth with the least distortion. For the lower teeth it is only necessary to rest the head well back in the head-rest. In making these adjustments the aim should be to seat the patient in such a position that the film, when in place, will face the tube so that the rays will be received perpendicularly thereon. It should be borne in mind that clearness of definition and correct proportions are lost if the plate is not at right angles with the tube.

187. While there is very little danger of producing a burn upon a patient in taking a dental skiagraph, owing to the shortness of exposure, the tube should nevertheless be placed at least 12 inches from the surface of the face. Although the time of the exposure is lengthened by increasing the distance between the tube and the film, even 15 inches would not be too far, and with an efficient instrument it should never be less than that. It should be borne in mind that the rays emanate from a very small surface and proceed outwards in straight but diverging lines, and the farther the object is stationed from the target, as the point of illumination is sometimes called, the more parallel will the rays be. Every skiagraph is larger than the original, but this disparity becomes less by placing the object at a distance from the tube. Nor are these the only advantages to be derived from operating at a distance from the tube. The patient, always a little timid at first, feels more secure at a greater distance and the operator has more room for manipulation. While a greater distance requires more time,

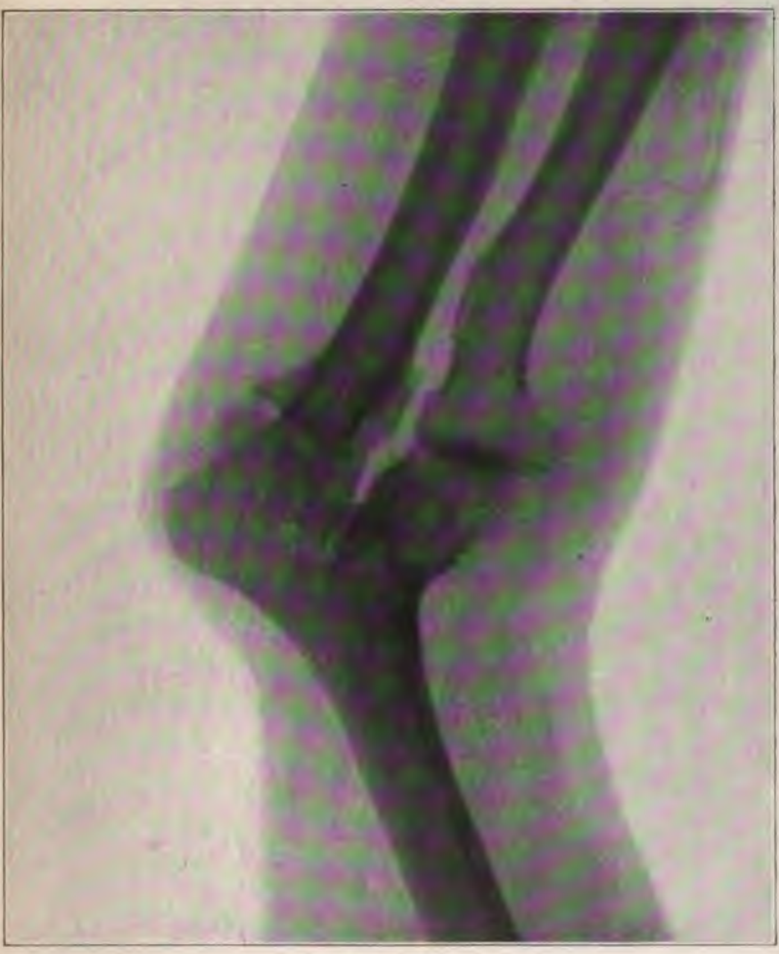

PLATE XXXIX.

Arthritis Deformans After Fracture of the Coronoid Process of the Ulna.

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the dental operations naturally require so little that this may be doubled and yet not be too long. The increase of distance is also compensated for in another way; while it may take a longer time, any movement of the patient is not so largely magnified as it would be if the distance were less. It may be roughly stated that the time required is proportionate to the square of the distance from the tube. If it is found by experiment that with a certain condition of tube it requires 15 seconds at 12 inches from the tube, the operator will find that to get the same result 24 inches from the tube, about 1 minute will be required, and all intervening distances in a proportionate length of time.

It will be found, in practice, that about 15 inches from the target is the proper distance, and having once established a distance it should be kept as nearly as possible thereafter. There are so many variable conditions in the taking of a skiagraph that those that can be fixed should be so.

188. When the distance has been settled upon, the dentist, in determining the length of time, has then to deal with but two variable conditions—the thickness of tissue and the condition of the tube. The thickness of tissue in dental cases does not vary as in general practice, and it is an easy matter to roughly estimate this factor. The following scale of the proportionate length of time, as to the thickness of tissue, may be established. If it is found that 5 seconds, with a certain condition of tube, will give a clear skiagraph of the lower incisors, it will require about 8 seconds for the molars of the lower jaw, and about 15 seconds for the antral region of the upper, and all the other parts at proportional lengths of time.

189. The condition of the tube has much to do with the length of time for an exposure. It will be found that the tube does not always start off at its highest efficiency, and it is this factor that is most variable and that will require the most careful consideration in timing the exposure. This cannot be determined by any standard, and the operator's skill, judgment, and experience are alone to be relied on. During the long exposures on the thicker parts, the physician has an opportunity to watch the tube through the fluoroscope and to judge as to the length of time but the dentist, owing to the short time of most of his exposures, must base his calculations upon the fluorescent appearance of the tube itself. For this reason, it is incidentally mentioned that darkening the room somewhat during the exposure will aid the dentist in judging of the working of the tube.

The tube varies at different times, not only as to the volume of Roentgen rays given off, but as to the condition of the vacuum. The length of the exposure, all other things being equal, has to do with the clearness of the picture, but the variation in the vacuum of the tube has to do with the contrast between the tissues of different density. The effect of tubes of different vacua is a most important consideration in Roentgen ray work, for on this depends almost entirely the securing of a good picture that will show the object or condition most clearly. A tube, for instance, that would best show a broken broach will give but an indistinct outline of the pulp canal or an abscess. Roentgen ray tubes have therefore been classified according to the condition of their vacua into soft, medium, and hard tubes. The soft tube, if used in looking at the hand through the fluoroscope, will show a dark outline of the whole hand, and only by close inspection can the bones be distinguished. This is represented by an external shunt spark of about 2½ inches. The medium vacuum is one that, if observed in the same way, will show the bones with the strongest contrast if compared with the flesh. They appear black, and, on inspection, their minute structure can be very easily seen and studied. The hard tube is one that will show the outline of the flesh and the bones within, but there is not that contrast between the two that was seen in the medium tube. The light seems to penetrate the two almost alike, and because of the loss of contrast, the minute structure of the bone cannot be traced in its finer details, as could be done with the medium vacuum.

190. The rays emanating from a soft tube have little penetrating power, whereas the rays from a hard tube have high penetrating power. For this reason the rays of the soft tube are affected by the least variation of the density of the softer tissues, while those of the hard tube pass through all tissues with but slight change. It should be borne in mind that a photographic plate is more sensitive than the eye, so that in the taking of a skiagraph the vacuum should be much lower than would be necessary for the eye, and it is for this reason that a lower vacuum is used for photography than for viewing the object through the fluoroscope. The vacuum, however, must be high enough, in all cases, for the rays to penetrate the subject. For this reason, also, it will be found that the degree of vacuum should vary somewhat in proportion to the thickness of tissue to be skiagraphed. It will require a little higher vacuum for the arm than for the hand, and a still higher vacuum for the pelvis. There is not only this rising scale of vacuum with increase of density and thickness that must be considered in the taking of every skiagraph, but the more important consideration of proper vacuum for showing the object or tissue at its advantage. The two must be considered together in calculating for the exposure. The physician is constantly dealing with tissues of a wide range of thickness and density, and only by constant practice is he able to successfully take every subject. While the dentist is more fortunate in this regard, because his dental cases are nearly all of the same thickness and density, he, however, has a range of subjects that call for just as fine vacuum calculations. The degree of penetration necessary in dental cases is about equal to that met with by the physician in the case of the hand, so that having once found the proper vacuum for the average dental cases, he has only to vary that slightly to get contrast or penetration. The average condition of vacuum necessary for dental cases will be found in a soft tube and at no time a higher vacuum than a medium tube.

191. There is a great variety of Roentgen ray tubes upon the market, and these are divided into two classes, namely, those with vacuum regulators and those without. The beginner, owing to the many details to be learned, should confine himself to the use of the latter class, for here he is dealing with a fixed vacuum, and that feature of his calculations may be omitted for the time being and taken up later when he is better prepared. The dentist should begin with two tubes, one soft and the other of a medium vacuum. These tubes are not only cheaper, but they will, later on, be useful to him in another way, for in the course of time as their vacua rise by use, these tubes can be used for fluoroscopic examinations and for work upon the thicker parts. Another and very important reason for using tubes with a fixed vacuum for dental purposes is because of the very short time required in these cases. All tubes with regulating devices are at a normally high vacuum, and it takes a few moments of time to "work" them down; so that, in practice, it will be found that by the time the tube has been brought to a condition of vacuum suitable for a dental case, the film has been exposed long enough and it will be a chance result if the skiagraph is a good one. After the dentist has learned how to manage the tubes with vacuum regulators, he may be able to get the tube in condition and dexterously adjust the patient and film and use the tube before the vacuum rises, but this can never be as satisfactory as a tube with a fixed vacuum and in condition for immediate use.

Physics of Light and Cautery

ELECTRIC HEATING

1. Loss of Electromotive Force.—The phenomena connected with the passage of electric currents through conductors have been treated fully in Volume 1 of this Course. Among the phenomena considered were those relating to chemical decomposition, electromagnetism; induction, and, finally, mechanical effects, as in electric motors.

In every instance, when work was performed in some form or other, the current lost part of its energy by losing part of its electromotive force. In other instances, when no visible work was performed, a certain part of its energy was lost in overcoming the resistance of the electric circuit. An instance of this kind is found in voltaic batteries, where the internal resistance often equals that of the whole external circuit. In this connection it will be remembered that the rule was given in Art. 134, *Direct Currents*, that "a maximum current is sent through a given external resistance, when the resistance of the battery is equal to the external resistance." It seems that here, and in other similar combinations, a great waste of energy must be going on, and the question naturally suggests itself: What becomes of this electric energy, which apparently disappears without leaving any visible traces behind?

2. Transformation of Energy.—As energy cannot be lost, it must, if disappearing in one form, reappear in some other form, and though the new form in which it reappears is not perhaps at once traceable, it is, nevertheless, present and will be found on closer investigation.

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It is a fact proved by numerous experiments, that whenever a resistance is placed in the path of an electric current, it can overcome the resistance only by giving up part of its energy to the material of said resistance, and that the energy then reappears in the form of heat. As this heating property of the electric current is made use of in cauteries and electric lamps it is important to find the relations between the electric energy expended and the heat developed, when various forms and kinds of conductors are used.

3. Variation in Heating Effects.—In order to fully grasp this subject it is necessary briefly to mention a few facts relating to heat and its effects on different substances. If we take a piece of copper and hold it over the flame of a Bunsen burner for a certain specified time and then measure its temperature, we will find that the latter is very different from the temperature gained by a similar piece of platinum exposed to the same heat and for the same length of time. The latter will show a temperature about three times higher than that of the former. A still greater difference is found if a piece of carbon is heated. Continuing our experiments, we will soon ascertain that metals, fluids, etc. all show a difference in their ability to receive heat from some source or other.

SPECIFIC HEAT

4. We may briefly explain this by supposing that each molecule of matter requires the same amount of heat to raise its temperature a certain number of degrees. The lighter the molecules of which a body is made up the more of them there must be to make up a certain mass. And, further, the greater the amount of molecules a body contains the more heat it will require to raise its temperature. Bodies of higher specific gravity contain a smaller number of molecules in a given mass, because each molecule weighs more. There being fewer molecules to heat, it will require less heat to raise the temperature of the whole mass. We see, then, that there is a close relation between the *thermal capacity* or *specific heat* of a body and its *specific gravity*.

5. Unit of Heat.—It is too indefinite to say that more heat is required to raise the temperature of one piece of metal than that of another piece, and some unit must therefore be adopted to enable us to make a comparison between various quantities of heat. For this purpose that quantity of heat has been selected which is able to raise the temperature of 1 cubic centimeter of water, that is 1 gram, from 3° to 4° C. This unit has been named 1 *calorie*. Five calories will therefore be able to raise the temperature of 1 gram of water 5° C., or 5 grams of water 1° C., and, similarly, any other combination of grams and calories, the product of which will be equal to 5 calories.

6. Table of Specific Heats and Gravities.—In the table below are given the specific heats and specific gravities for various substances. Water is there taken as unity, meaning that if it will take 1 calorie to raise the temperature of 1 cubic centimeter of water 1° C., it will require a fractional part of 1 calorie to raise the temperature of any of the other substances there named to the same height. For instance, lead would require only .0314 calorie, etc.

TABLE I

Substances	Specific Heat	Specific Gravity
Lead	.0314	11.4
Platinum	.0324	22.1
Silver	.0611	10.5
Copper	.1013	8.9
Zinc	.1015	6.9
Iron	.1218	7.8
Graphite	.2018	1.6
Water	1.0000	1.0

7. Relations Between Specific Heat and Specific Gravity.—There is some similarity between thermal and electrostatic capacity. If the latter is small, it requires a small electric charge to raise the pressure to that of 1 volt; and, similarly, if the thermal capacity or specific heat is small, takes a small amount of heat to raise the temperature 1° C.

In general, it is found that with an increase in specific gravit there follows a decrease of specific heat. Lead and iron ar exceptions to this general rule.

An examination of the values given for specific heat will show that it takes twice as much heat to raise 1 pound of silver to the same temperature as that of 1 pound of platinum, and nearly 4 times more heat to raise iron to the same temperature as that of lead. If, for instance, two rods, one of silver and one of platinum, were held together over a Bunsen burner, it would shortly be found that the platinum rod was red hot, while the silver rod would be comparatively cool.

8. The Joule, Watt, and Calorie.—Having now ascertained the meaning of specific heat and a calorie, the relations between the calorie and electrical work have to be found. It was just stated that while an electric current was passing through a conductor the resistance of the latter had the effect of changing part of the electric energy into heat. Heat must, therefore, simply be another form of electric energy, and, as it was possible to express the energy of the electric current in foot-pounds, it should likewise be possible to express the energy of heat in the same unit.

The unit of electrical work is the *joule*, which was found to equal .7373 foot-pound. (See Art. 15, *Direct Currents.*) It has been found that

1 calorie = 4.2 joules = 3.07 foot-pounds.
1 joule = .24 calorie = .7373 foot-pounds.

As 1 watt = 1 joule per second and 1 joule = .24 calorie, it follows that 1 watt = .24 calorie per second.

9. Heat Developed in a Conductor Proportional to Square of Current-Strength.—In Art. 20, *Direct Currents*, the following formulas for finding the number of watts developed were given:

$$W = E \times C = \frac{E^2}{R} = C^2 R.$$

The last of these only will be used in finding the relation between the current passing through a conductor and the heat developed in it.

This formula $W = C^2 \times R$ shows that when heat is produced in an electric conductor, it is not proportional simply to the number of amperes passing, but to the square of the same. If, for instance, 2 amperes is flowing and transformed into heat, 4 amperes will not simply double the quantity of heat developed, but will increase it 4 times. Why this increase should be proportional to the *square* of the current-strength may not seem quite clear, and a practical example may help to make the matter better understood. When chemical energy is transformed into electrical energy, as, for instance, in a voltaic cell, the amount of material consumed per hour is proportional to the strength of the current. Suppose six Daniell cells are connected in series and are sending a current of 1 ampere through an external resistance. As the consumption of zinc per cell amounts to .043 ounce per ampere for each hour, the total amount of zinc consumed amounts to 6 × .043 = .258 ounce. If it is desirable to increase the current-strength to 2 amperes, while the resistance remains constant, then the E. M. F. must be doubled and therefore the number of cells increased to 12. As now each cell is transmitting a current of 2 amperes, twice the amount of zinc must be consumed, or .086 ounce per cell, and the number of cells now being 12, the total amount of zinc consumed is 12 × .086 = 1.032 ounces. This is 4 times .258 ounce, the original amount. We see then that to double the current-strength, 4 times as much chemical or electrical energy had to be developed, the electrical energy being proportional to the amount of material chemically transformed.

10. Conclusions.—From these considerations we come to the conclusion that the greater the number of watts transformed into heat the more rapidly the temperature must rise. Contrarily, the higher the specific heat of a conductor, or its capacity for heat, the more slowly will this rise take place, and, finally, the greater the mass or weight of the conductor the more time will be required to effect a rise in temperature.

CONDUCTION, CONVECTION, AND RADIATION

11. The increase in temperature of a conductor does not, as a rule, keep step with the number of watts spent in heating it, because heat, like electricity, is subject to losses from various causes. These losses may take place in three different forms, through conduction, convection, and radiation.

In *conduction*, the heat is transmitted from particle to particle in the body itself. In a heated electric conductor the heat would leak from the interior to the surface.

The transmission of heat by *convection* takes place in liquids and gases only, as it requires a certain mobility of the molecules of the substance. If a beaker of water is placed over a Bunsen burner, the bottom will become heated and the particles of water situated immediately above the same will be heated by conduction. When heated they become lighter and rise to the surface, thereby giving room to other particles. In this manner a constant stream of water will carry off the heat supplied by the bottom of the vessel.

When *radiation* goes on there is no direct contact between the source of the heat and the recipient of the same. The ether is in this case the transmitting medium and is able to transfer the heat from one place to another without itself being heated. For instance, the sun radiates its heat through space and in this manner supplies the earth with its necessary heat, but without heating the intervening medium.

12. Limit to Increase of Temperature.—A heated conductor may give up its heat by either one or all of these forms. If exposed to the air, the latter will become heated and, in passing away, set up a current that will constantly carry off heat from the conductor. The amount of surface a conductor exposes to the air will therefore be of importance in determining the rise in temperature. Thin wires heat more rapidly than thick wires of the same material, partly because they have less surface to dispose of the heat and partly because of the higher resistance. Suppose, for instance, that two wires, one $\frac{1}{32}$ and the other $\frac{1}{64}$ inch in diameter, have to carry the same current. The thinner wire will have a cross-sectional area $\frac{1}{4}$ that of the thicker; therefore, it has 4 times greater resistance and 4 times more heat units developed in it. But, as these heat units act on a mass 4 times smaller than that of the larger wire, there will be an increase in temperature 16 times greater in the smaller wire. Then again, it must be remembered that the smaller wire has a surface only one-half that of the larger wire, and consequently it will have more difficulty in getting rid of the surplus heat. As the thin wire grows hotter it will also increase in resistance, and its temperature will continue to rise until it has reached a point where there is a balance between the heat received and that given off by conduction and radiation.

13. Effect of Length.—If the resistance of a long conductor is the same as that of a short conductor with the same diameter, the number of heat units developed in both should be the same. But the increase in temperature of the long conductor may be hardly noticeable, partly because the heat has to be distributed over a larger mass and also because the longer wire has a greater radiating surface.

14. Effect of Heat on Resistance.—As already stated, the resistance of a metallic conductor increases with the temperature. The amount of this increase is about .38 per cent. per degree centigrade for pure metals. For instance, if a copper conductor has a resistance of 220 ohms and its temperature is raised 100° C., its resistance will increase to about 304 ohms. In general, it may be said that conductors *increase* and insulators *decrease* in resistance, when heated.

Certain metallic alloys used for high-resistance coils suffer a very small increase in resistance when heated, and some of them, notably manganin, actually decrease in resistance. Carbon and india-rubber decrease in resistance when warm, the latter very much so, even with a small increase in temperature. The increase in conductivity of carbon amounts to about .03 per cent. per degree centigrade. For instance, if the carbon filament of an incandescent lamp has 220 ohm's resistance, it will be reduced to 213 ohms at an increase in temperature of 100° C., and to 135 ohms at an increase of 1,280° C., wl is the usual difference in temperature between hot and cold.

Liquids decrease in resistance by an increase in temperatu Water, when absolutely pure, does not conduct, but when mix with gases or saline bodies, it is able to act as a conductor an its resistance will then depend on the resistance and quantity c these foreign substances. If 8 per cent. of sulfuric acid i added to the water, the resistance will decrease .65 per cent. per degree centigrade, so that a column of water with 1,000° ohm's resistance will, when the temperature is increased 100° C., have its resistance reduced to 350 ohms.

15. Different Temperatures in One Conductor. If part of a heated conductor, such as a cautery, be either cooled or heated, it will influence the total resistance of the circuit and increase or decrease the current-strength. Suppose, for instance, that a glowing cautery is brought in contact with living tissue. Part of it will then be cooled off, its resistance will be lowered, and the amperage will be increased. Consequently, the parts unaffected by the tissue will grow hotter. On the contrary, if the same part of a conductor has heat imparted to it, its resistance is increased, the current is reduced in strength, and the adjoining parts grow cooler. In the first instance, the outlying parts of the cautery may grow so hot as to fuse, therefore the importance of providing means, such as a rheostat, for regulating the current-strength through an active cautery.

16. Importance of Low Resistance in a Cautery Circuit.—As the cautery itself is of a very low resistance, it follows, as a consequence, that if a large amount of heat shall be developed in it, a current of high amperage is required. Under these circumstances a heavy current will naturally have to pass through the whole circuit, inclusive of the battery itself, and, if no heat shall be developed anywhere but in the cautery, it follows that the other parts of the circuit must have a resistance much lower than that of the cautery. If this is not the case, heat will also be developed in places where it is not desired, and where it would either be inconvenient to the patient or to the operator, besides being a useless waste of power.

For instance, if the cautery holders or the conductors leading to the latter are too small in diameter, then they are liable to get heated and in this manner will not alone waste heat, but will also, by their increase in resistance, reduce the current-strength and prevent the cautery from receiving its full quota of the total energy at disposal. A few examples will show the importance of this point.

A battery *B*, Fig. 1, producing an electromotive force of 4 volts and with an internal resistance of .02 ohm, is to supply the current to a cautery *C* of .035 ohm's resistance, and it is desirable to find the effect that the resistance of the conductors *W* between the cautery and battery will have on the current-strength of the latter. It is supposed that 20 amperes are required to heat the cautery and that two conducting-cords, of a joint resistance of .006 ohm, connect the battery and cautery. The total resistance of the circuit is, then, .02 + .006 + .035 = .061 ohm. If no rheostat is in the circuit, the current-strength $C = \frac{E}{R} = \frac{4}{.061} = 65.6$ amperes. To reduce this current to 20 amperes, a rheostat is installed and a resistance of .139 ohm is inserted so as to make the total resistance .2 ohm. By means of the rheostat this supplementary resistance may be increased or diminished as the circumstances may require. This extra resistance of .139 ohm corresponds to a loss in voltage of 2.78 volts, which is changed into heat in the rheostat.

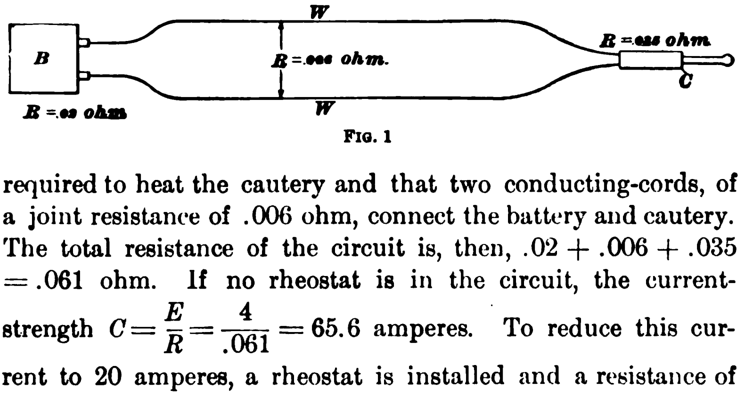

FIG. 1

If these conducting-cords of .006 ohm's resistance are replaced by some of .12 ohm's total resistance, the resistance of the whole circuit will be .02 + .12 + .035 = .175 ohm, and the maximum current-strength is $C = \frac{4}{.175} = 22.9$ amperes. There is now a surplus resistance of .2 — .175 = .025 ohm, only which represents a loss in voltage of 20 amperes × .025 ohm = .5 volt, which is a very small margin when it is considered that the heating of the circuit will increase the resistance materially and that a bad connection somewhere may consume this surplus. If the whole resistance of the rheostat were switched out, it would in this case have little or no compensating effect on the increased resistance of the circuit. The influence of the two conductors will be more clearly shown in the following table:

TABLE II

	Conductor of .006 Ohm's Resistance	Conductor of .12 Ohm's Resistance
Resistance of cautery	.035 ohm	.035 ohm
Resistance of circuit exclusive of rheostat	.061 ohm	.175 ohm
Resistance of circuit inclusive of rheostat	.200 ohm	.200 ohm
Surplus resistance in rheostat	.139 ohm	.025 ohm
Surplus voltage consumed in rheostat	2.780 volts	.500 volt
Current in the circuit with rheostat	20.000 amperes	20.000 amperes
Percentage of total pressure lost in conducting-wires	3.0	60.0
Percentage lost in cautery	17.5	17.5
Percentage lost in battery	10.0	10.0
Percentage lost in rheostat	69.5	12.5

17. Cautery Battery of Low Resistance.—When it is so important to reduce the resistance of the conductors to a minimum, it can easily be seen that the resistance of the battery must also be as small as possible. Suppose, for instance, that the attempt should be made to run the above cautery by means of two Leclanché cells, each with an E. M. F. of 1.7 volts and internal resistance of .8 ohm. Arranging the cells in series, their joint pressure will be 3.4 volts and their resistance 1.6 ohms; adding to this the resistance of the conducting-cords and the cautery, the total resistance will be 1.6 + .006 + .035 = 1.641 ohms.

Therefore, $C = \frac{3.4}{1.641} = 2.072$ amperes, instead of the 20 amperes required. As it was shown in Art. **138,** *Direct Currents,* that an increase in the number of cells in series with a small external resistance does not increase the current-strength, it is useless to add any more cells. The only possible improvement would be to connect the cells in parallel. Then the total pressure would be that of one cell, or 1.7 volts, and their joint resistance $\frac{.8}{2} = .4$ ohm. The total current would then be $\frac{1.7}{.4 + .006 + .035} = \frac{1.7}{.441} = 3.8$ amperes, which is still entirely inadequate. It would take ten of these cells in parallel before a current of sufficient strength could be obtained. Even so, a battery of these cells would be unsuited for the purpose, because cells of this class are unable to furnish a heavy current except for very short intervals, polarization taking place very rapidly, reducing the current-strength.

If we select some cells with a higher E. M. F. and lower resistance, such as bichromate cells or cells with very low internal resistance as, for instance, the Edison-Lalande cell, better results will be obtained. Selecting two cells of the latter class with an E. M. F. of .7 and an internal resistance of .03 ohm, we would, by arranging them in series, receive a current of $C = \frac{2 \times .7}{2 \times .03 + .006 + .035} = \frac{1.4}{.101} = 13.8$ amperes. This is, also, entirely insufficient, but we notice at once the advantage over the other two cells in series. To obtain something like 20 amperes from this class of cells, four are required, arranged two in series and two in parallel.

When the minimum internal resistance is desired, we have to resort to the storage-battery, where the resistance may be about .005 ohm and where the discharge, theoretically, may be at the rate of $\frac{2.0}{.005} = 400$ amperes. This high rate of discharge is, of course, not permissible, because it would ruin the plates; but even so, the possible rate of discharge is so high that an ordinary voltaic battery cannot compete with it.

The method pursued above for ascertaining the current-strength is to use formula (*a*), Art. **128,** *Direct Currents.* This is usually sufficient, but those who wish to go a little further may use formulas (*d*) and (*e*), Art. **135,** and formula (*g*), Art. **136.**

CURRENT-SUPPLY FOR THE CAUTERY

18. The Bichromate Cell.—Regarding the most convenient method for supplying the current to the cautery, it is needless to say that the ordinary lighting circuit takes first place, next to this comes the accumulator, and last the primary cells. Among the latter, the *bichromate cell*, Art. **35,** *Direct Currents*, has occupied a prominent place, because it has a high E. M. F., a comparatively low resistance, and is able to deliver a heavy current for some time without polarization. There are many forms in the market, mostly consisting of a combination of a number of single elements. Fig. 2 shows a form provided with a tight cover, which allows the liquid to splash about inside without spilling. In a bichromate cell the zinc should always be removed when not in use, in order to prevent local action. This is here accomplished by raising the cover and turning it around so as to place the plates in the empty side of the case. The other half is divided into cell-compartments, each containing an electrolyte. Fig. 3 shows another form where the electrolyte is kept in a bottle when not in use. Numerous other forms are produced, so as to make the

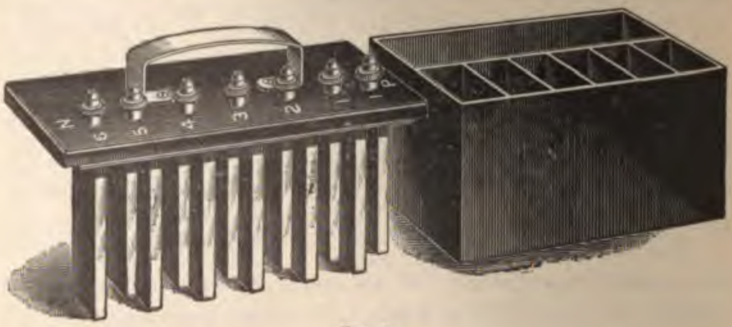

FIG. 2

cells more portable. These cells all need a certain amount of care, if they are to be relied on when wanted. If not systematically inspected, they are liable to fail when any heavy service is required of them.

In Arts. **92** and **94**, *Direct Currents*, are given some particulars relating to the care of these cells. It should here be added that in a bichromate cell there is no liberation of gas and, therefore, no motion takes place in the electrolyte whereby the exhausted parts of the solution may be made to move away and make room for the fresh parts. The strengthening of the old solution goes on mostly by means of diffusion, unless the plates are lifted at intervals so as to set the liquid in motion. It is therefore of importance to have the electrolyte in a concentrated form, and this cannot be done with bichromate of potassium, even if dissolved in hot water. But, if bichromate of sodium is used in its place, it can not alone be dissolved in cold water, but almost in any quantity. A battery will then need less frequent renewals of the electrolyte, and will be able to furnish a heavier current for a longer time without being subject to a decrease by the diminished action of the electrolyte. Carhart recommends the following solution: Dissolve 7 ounces of sodium bichromate in 1 quart of water, and to this should be added 5 fluid ounces of strong sulfuric acid. The solution is ready for use as soon as it cools. When the battery begins

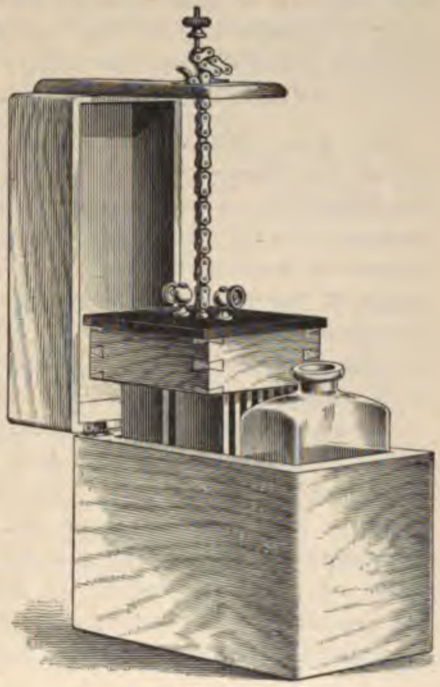
FIG. 3

to show signs of exhaustion, add from 1 to 1.5 ounces of acid per quart of fluid.

When it is intended to use a bichromate battery for cautery work, it is advisable not to have the zincs in contact with the electrolyte longer than is absolutely necessary, and after use the zincs should be washed out in water. If the cautery current has been one of great strength and taxed the battery to its limit, it is better to throw the liquid away, unless it still has sufficient strength to run the battery for other purposes where a current of small strength is required.

19. The Edison-Lalande Cell.—When a battery is desired for office-work alone and not for transportation, then the *Edison-Lalande* battery is very serviceable. It will keep in working order for a long time without any attention, except an occasional examination every 2 or 3 months to ascertain the height of the liquid, as the latter will evaporate even when covered with oil. The type "W" cell has a resistance of about .02 ohm, and one cell can, for a short time, deliver a current of 33 amperes, if necessary; but usually they are put up in combinations of three cells, when they can also be used continuously for motors and similar work, and are able to supply a current of over 20 amperes. The lack of success that some operators have had with these cells is mainly caused by not following the rules given by the manufacturers. Another cell, based on the principles of the Edison-Lalande cell, is the *Gordon* cell. It is somewhat different in construction, but otherwise there is little difference between them.

20. Dry Cells.—Some *dry cells*, such as the "New Standard," "Hydra" battery, and others, have also been used for cautery work and to a great extent for lamps. They require no attention and are very suitable for transportation. Their resistance is not as low as that of the fluid cells and they cannot be renewed, but many operators prefer these disadvantages to those of having to keep the cells in working order and to handle acids, etc.

21. Care of Cells.—Regarding the care of cells, then, the essentials have already been given in Art. **92**, *Direct Currents*.

It may be added that sometimes a battery, which otherwise seems to be in perfect order, fails to give the usual current-strength. In this case the fault may lie with one single cell, which either has a wasted zinc or some loose contact. It is well, then, to give each separate cell a close examination and, preferably, to test them by means of a voltmeter.

22. Storage-Battery.—Whenever a storage-cell can be conveniently charged it is preferable to a primary cell, provided it is in frequent use. If this is not the case, then it is better to have one of the primary batteries mentioned, because a storage-battery, if not submitted to a certain amount of work, will deteriorate in a short time. The price paid for it had then better be devoted to a primary battery. Complete information about the storage-battery has already been given in Art. 57, *Direct Currents*.

The main point about a storage-battery is the rate of its discharge, taking care that it does not go beyond that indicated by the manufacturer. If so, buckling and sulfating are liable to occur, and it will never be able to run at its full capacity again. The charging of the battery should also be at the stated rate. As a transportable battery, it has great advantages by being able to deliver a heavy current without too much bulk. If regularly used, then a systematic charging process should be gone through with at regular intervals, so that the battery is always charged and ready for service. If the lighting circuit is not available, a primary battery must be resorted to, and then every available moment should be used for charging purposes. Otherwise a very large primary battery is required in order to finish the charging process within a reasonable time. When ordering a storage-battery, the purpose for which it is to be used should be stated, and also the means for charging it. The manner in which a primary battery is used for charging accumulators is fully described in *The Physics of Roentgen Rays*.

If the 110-volt incandescent-light circuit is utilized for charging purposes, then the arrangement shown in Fig. 4 may be made. The current comes in through the conductor *a* from the main circuit and passes through a number of incandescent lamps, depending on the desired current-strength. In this instance ten lamps of 16 candlepower are installed, each permitting ½ ampere to pass, therefore a total of 5 amperes. From here the current passes through a fuse and switch to the adapter, ammeter *A*, and accumulators. In parallel with the battery is inserted the voltmeter *V*, enabling the operator to ascertain the progressive state of the charging at the same time as the ammeter *A* indicates the rate at which it takes place. From the battery the current returns again through the adapter, switch, fuse, and main conductor *b*.

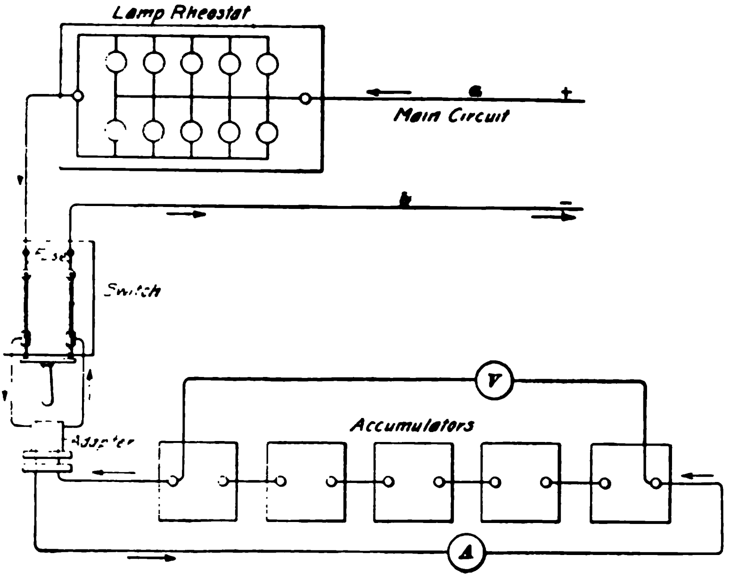

FIG. 4

When a primary battery is used for charging it is important to have a rheostat in the circuit whereby resistance may be thrown out of the circuit when the charging progresses. This is to counteract the counter E. M. F. of the accumulator, which constantly increases while the charging is going on, tending to decrease the current-strength. The latter should be kept as nearly constant as possible. If too great, gassing and buckling may be caused. The method for calculating the time of charging the storage-battery has been given in Art. **30**, *The Physics of Roentgen Rays.*

23. Lighting Circuit.—The minimum of attention is required on the part of the operator when the incandescent-lighting circuit is utilized. All that is required under this arrangement is simply to close a switch and the current is flowing. Ordinarily there are two kinds of currents available, the *direct* and the *alternating.* The most universally useful of the two is the direct current, because the alternating cannot be used in cataphoresis, electrolytic, and galvanic treatments. For cautery and lamps it is immaterial which current is used.

It would seem natural to suppose that a 110-volt lighting current could be used directly for cautery purposes, and that by inserting a resistance-coil or a number of incandescent lamps of suitable resistance in parallel, any current-strength could be obtained. But this method has certain drawbacks that make it objectionable. A cautery has a very low resistance, and, to send a current of the required strength through it, demands a comparatively low pressure. For instance, let the united resistance of the cautery and conductors be .1 ohm; then, with a pressure of 110 volts the amperage would be $C = \frac{E}{R} = \frac{110}{.1} =$ 1,100 amperes. As the required amperage rarely goes beyond 25, and usually is much below this, it is clear that a large resistance must be inserted in the circuit to bring the pressure within reasonable limits.

Suppose that we desire a current of 5 amperes for a cautery of .035 ohm's resistance. It is then necessary to insert a resistance in the circuit, in series with the cautery, sufficiently large to make the joint resistance of the cautery and conductors equal to 22 ohms, as found by Ohm's law, viz.: $R = \frac{E}{C} = \frac{110}{5} = 22$. Let the united resistance of the cautery and the conductors be .1 ohm, then the resistance of the rheostat would be $22 - .1 =$ 21.9 ohms. The reduction of pressure that takes place in this resistance is $E = C \times R = 5 \times 21.9 = 109.5$ volts, and the number of watts lost is $W = E \times C = 109.5 \times 5 = 547.5$ watts, a transformer *C*, where it is changed into a 6-volt alternating current, with a corresponding increase in amperage. This current is now led through the conductors *c, c* to the cautery *D*.

When buying apparatus of this class it is always advisable to specify the voltage of the circuit from which it is intended to derive the operating current. The construction of the apparatus varies with the variation in voltage. The motor can also be used for any other purpose where driving power is required, such as static machines, centrifuges, etc.

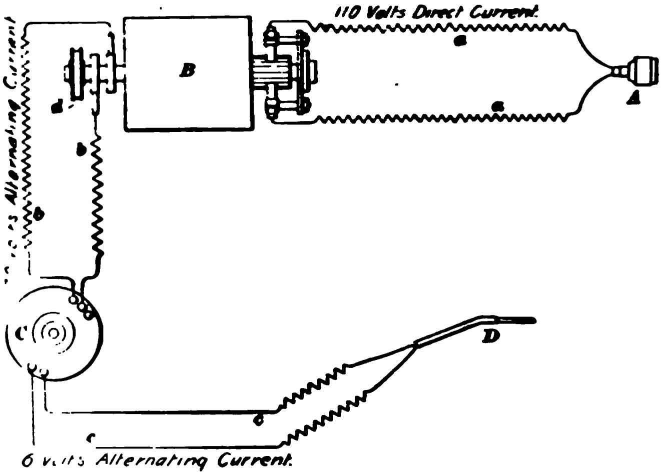

FIG. 7

CAUTERIES

24. In Art. **16** was explained the theory of the cautery, and it remains here to treat of its practical construction and of the variations in form that the various purposes for which it is used demand of it. Platinum is the metal that is almost exclusively used for cauteries, though at times thin steel and iron wires have been utilized for the same purpose. Platinum has the advantage over other metals that it is of a high specific resistance and low specific heat, and of a high fusing temperature, therefore not easily melted when exposed to a high temperature.

25. Construction of the Cautery.—The resistance of a cautery seldom exceeds .1 ohm, while the volts vary between 2 and 6 and the amperes between 1 and 50. A broad knife may take as much as 25 to 30 amperes at a pressure of 1 volt. If the cautery is a long, thin wire, considerable more E. M. F. may be needed, but the total energy transformed into heat may be small, because the resistance is higher.

Some cauteries are made rather heavy; this should be avoided, as thereby the resistance is lowered, and, consequently, a heavier current is needed to reach the same temperature. There is then more danger of the rest of the circuit also getting heated, resulting in an increase of resistance and waste of power. The copper conductors to which the platinum loop is attached should be of ample size and well insulated. The difference in pressure between these two copper wires is not great, but it is, nevertheless, important that no current passes from one to the other before it flows through the platinum loop. Therefore, the insulation should be good and should be of such material that it can be readily sterilized. Usually silk and asbestos are used for this purpose, being covered with varnish to make it waterproof. It is needless to say that absolute cleanliness should be the rule, so as to prevent organic matter from being lodged between the conductors.

26. Resistance of the Cautery Circuit.—In Art. **16** attention was called to the importance of having the whole cautery circuit, external to the cautery itself, of a minimum resistance. This emphasizes the importance of having all the joints and connections perfect, electrically considered. Metallic oxids are poor conductors, and, if found on any of the electrodes and joints, must at once be removed. For instance, the ends of the cautery that are inserted in the handle should always be examined, and, if oxidized, should be rubbed off with some fine emery-paper; likewise, the ends of the conducting-cords that are inserted in the other end of the handle. The connection between the several elements of the battery should also be frequently inspected, as corrosion is, in particular, liable to occur in the presence of acids.

It has already been remarked in Art. 15 that the cautery, after coming in contact with moist tissue, is considerably cooled. As a consequence, some allowance should be made so that the cautery may receive a somewhat heavier current when in active operation than that which seems sufficient to make it glow while surrounded by air.

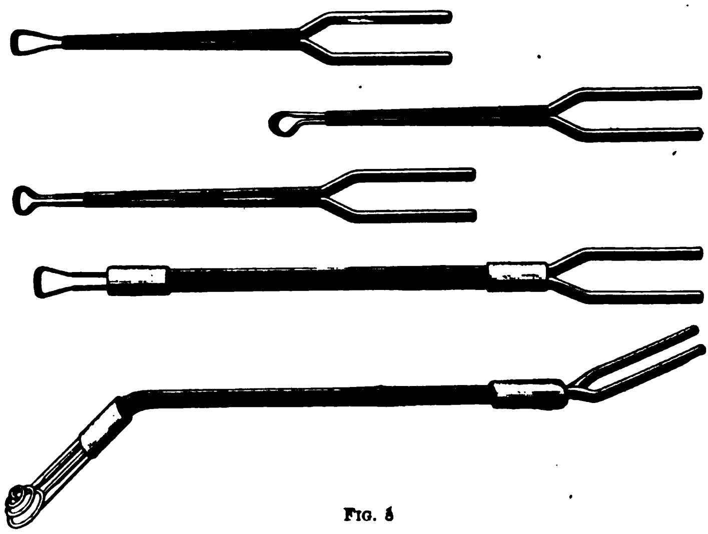
FIG. 8

27. Variety of Cauteries.—Fig. 8 shows a few forms of cauteries most in use. Where a larger incandescent surface is required, a loop or spiral of platinum, supported in grooves on a porcelain mount, is made as shown in Fig. 9, the porcelain being heated to redness with the platinum.

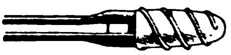
FIG. 9

28. Cautery Handle.—Fig. 10 shows the cautery handle into which any of the cauteries may be inserted and, likewise, part of the conducting-cords by which the current is sent from the transformer to the cautery.

The aim should be to have the cautery handle light and well balanced, otherwise the delicacy of the operations, for which the cauteries, as a rule, are used, are interfered with.

The metal handle should be well insulated from the end sockets into which the conductors and cautery are inserted.

Some handles are provided with an interrupter for starting and stopping the current through the cautery. This has some objections, mainly this, that the hand of the operator has to perform an additional motion, which of necessity must interfere with the stability of the cautery. A better method would be to use a foot-switch or to have an assistant do the starting or stopping of the current.

29. Cautery Snare.—For the removal of a greater quantity of tissue the electrocautery snare is used. The ordinary handle, as shown in Fig. 10, may also be used for operating this snare, and is then provided with a little wheel by means of which the platinum snare may be drawn up. This arrangement does not seem to be very satisfactory, as it is difficult to produce an even pull and to prevent a certain jerkiness. In many operations where the cautery snare is used, it is required to submit the latter to a constant pull, and, in some cases, of considerable strength. The handle, Fig. 11, is constructed with the aim of fulfilling these requirements. Here the fingers are inserted in the three rings, and by bending the fingers towards the thumb, the snare is drawn in with an even motion and with a speed that can be easily regulated. When using the snare it should be remembered that, while it is being drawn into the handle, its resistance is constantly decreasing. The resistance of the circuit should, therefore, be correspondingly increased, otherwise there is danger of the platinum wire being overheated and

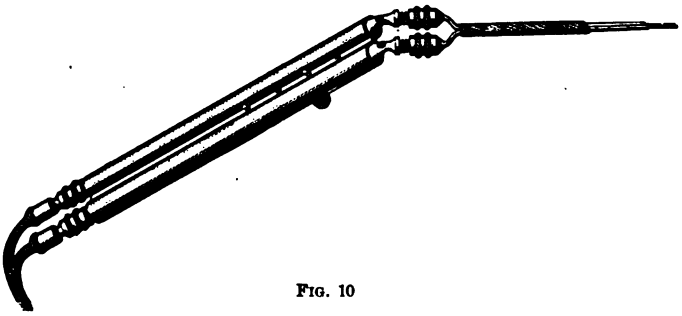

FIG. 10

melted. The snare handle here illustrated has a resistance that is automatically increased while the snare is being shortened.

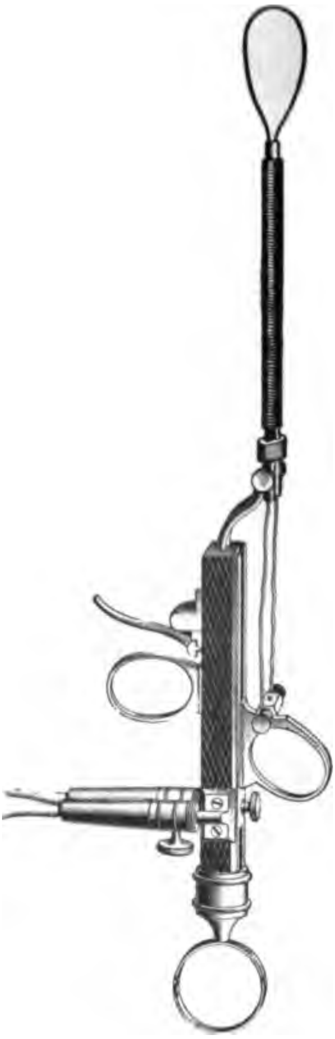

FIG. 11

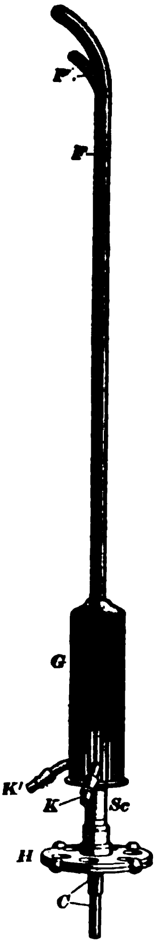

FIG. 12

30. Bottini's Incisor.—A special form of cautery is *Bottini's* incisor, Fig. 12, used for incision of the prostrate gland. The female shaft *F* contains the cautery knife *P*, which may be moved in or out by turning the wheel *H*. To keep the shaft cool while the cautery is heated, a stream of cool water is circulated through the handle *G* and shaft *F* by letting the water pass in through the pipe *K* and out through the pipe *K'*. *C* is a plug that, inserted in a sleeve, connects it with the copper conductors. The advantage of the cautery is perhaps here shown at its best. While the shaft is being inserted the blade *P* is entirely covered and the whole is cold. The current is sent through the cautery after the desired position has been found and the operation performed in about a minute, after which the cautery is again sheathed, the current cut off, and the whole withdrawn in a cool condition.

ELECTRIC LIGHTING

INCANDESCENT LAMPS

31. The Filament.—The active part of an incandescent lamp is a thin filament of carbon mounted on platinum wires that are sealed in the neck of an evacuated glass globe. The thickness of the filament determines the resistance of the lamp and, thus, the voltage necessary to send a current of a given strength through it. In some small lamps a platinum wire is used in place of the carbon filament. More care is then required in using the lamps, as a current of too great intensity is liable to fuse the platinum.

32. Unit Candlepower.—The light that an incandescent lamp emits is measured in candlepowers, some lamps having as little as ½ candlepower and others as much as 1,000. The standard candlepower is the light produced by a candle burning 2 grains of spermaceti wax per minute.

33. Variation in Candlepower.—The lamps ordinarily used for offices and operating-rooms are 16 candlepower, which is abbreviated to 16 c. p. The number of candlepowers that a lamp is able to give out depends on the amount of electric power that the lamp transforms into light and heat. We have already seen that electric power is measured in watts, and the number of watts that a lamp utilizes is found by multiplying together the pressure and strength of the current through the same.

For instance, the resistance of a lamp may be 220 ohms and the voltage 110. The current-strength is then $C = \frac{E}{R} = \frac{110}{220} = .5$ ampere. The product of voltage and amperage is $110 \times .5 = 55$ watts. The number of watts required to produce 1 candlepower varies between 3 and 4.5; small lamps used for diagnostic purposes may require as much as 8 watts per candlepower. Counting, in this instance, 4 watts per candlepower, we find the candlepower of this lamp to be $\frac{55}{4} = 13.75$. This is when the lamp is new, but its candlepower is not constant. A gradual decrease of the latter goes on, caused partly by the disintegration of the carbon filament, whereby its diameter is reduced and its resistance correspondingly increased, and partly, also, by the deposition of the removed carbon particles on the inside of the lamp-globe. The latter is thereby made more or less opaque and the efficiency of the lamp reduced.

The lamps used for diagnostic purposes vary in illuminative power from 1 to 16 candlepower. The pressure required for their operation is usually between 4 and 110 volts. It is clear that the same candlepower may be produced by lamps of varying voltage and amperage as long as the watts consumed are the same. For instance, a lamp of 10 volts and .75 ampere would, theoretically, have the same candlepower as one with 6.5 volts and 1.25 amperes. In both cases the number of watts utilized is 7.5, but in general it is found that lamps using more than .9 ampere are more efficient than those requiring a smaller current-strength.

The table on the following page shows, approximately, the variations in voltage and amperage for the same candlepower.

34. Selection of Lamps.—When procuring ordinary diagnostic lamps, considerations should be had of the available voltage and a lamp selected that is most suitable for it. To be on the safe side it is well, for small lamps, to count about 8 watts per candlepower. The following example will show how such calculations are to be carried out. To find the total number of watts required for a lamp of a given candlepower, multiply the candlepower of the lamp by the number of watts per candlepower, or, total watts $W =$ total candlepower × watts per candlepower. For example, an 8-candlepower incandescent lamp requires 3.5 watts per candlepower; how many watts are needed for its operation? $W = 8 \times 3.5 = 28$ watts. A current of 10 volts is available; how many amperes will it require? According to Art. **20,** *Direct Currents*, $W = E \times C$, therefore, $C = \frac{W}{E} = \frac{28}{10} = 2.8$ amperes.

TABLE III

1	c. p.	from	3 volts and	.8 ampere	to	8	volts and	.3	ampere
2.5	c. p.	from	5 volts and	1.4 amperes	to	25	volts and	.45	ampere
5	c. p.	from	5 volts and	3.0 amperes	to	65	volts and	.35	ampere
8	c. p.	from	10 volts and	2.8 amperes	to	120	volts and	.3	ampere
16	c. p.	from	15 volts and	3.7 amperes	to	160	volts and	.4	ampere
25	c. p.	from	40 volts and	2.2 amperes	to	120	volts and	.7	ampere
32	c. p.	from	50 volts and	2.3 amperes	to	120	volts and	.9	ampere
50	c. p.	from	50 volts and	3.5 amperes	to	120	volts and	1.4	amperes
100	c. p.	from	50 volts and	7.0 amperes	to	120	volts and	2.9	amperes

35. Selection of a Battery.—The same battery that will serve to operate a cautery will not, as a rule, be able to run an incandescent lamp unless the battery is rearranged to fill the new requirements. The reason for this is that in a cautery we have to do with a very low resistance, perhaps as small as .025 ohm, while in an incandescent lamp the resistance may be as high as 400 ohms, depending on the candlepower of the lamp and the pressure of the current. In the cautery it is a question of developing a maximum of heat, and in the incandescent lamp a minimum heat with a maximum of light.

As the lamp has a resistance so much higher than that of the cautery, it is necessary to have a battery with a high E. M. F.

and a relatively small current-strength. The resistance of the battery in this instance plays a more subordinate rôle, because the amperage is small, and, therefore, the product of current into resistance, that is, the loss of potential, cannot reach the height it would in a cautery circuit. It is thus seen, that while in a cautery-battery the aim is to produce a maximum current-strength by putting the cells in *parallel*, in an incandescent lamp-battery the aim is to produce a higher voltage by placing the cells in *series*. Whether either of these combinations alone is sufficient to produce the desired voltage or amperage will depend to a great extent on the E. M. F. and the resistance of the individual cells, and on the current-strength demanded either by the cautery or the lamp.

Suppose, for instance, that an incandescent lămp with a resistance of 4.8 ohms requires a current of 1.25 amperes to bring it to proper incandescence. A battery of six Edison-Lalande cells, used for the cautery, is at hand, and it is desirable to ascertain if these are able to run the lamp. The E. M. F. of each cell is .7 volt and internal resistance .03 ohm. Arranging the cells in series we find the current-strength, according to formula (*b*), Art. **128,** *Direct Currents*, to be

$$C = \frac{s\,e}{s\,r + R} = \frac{6 \times .7}{6 \times .03 + 4.8} = \frac{4.2}{4.98} = .84 \text{ ampere.}$$

The result shows that this number of cells is entirely inadequate for lighting this particular lamp. This does not mean that a greater number of cells may not do so, or that another lamp requiring less pressure may not be run successfully.

On taking six bichromate cells, each of 1.9 volts E. M. F. and .5 ohm's resistance, we find, on arranging them in series, that they will give a current of $C = \frac{6 \times 1.9}{6 \times .5 + 4.8} = 1.46$ amperes, a current of sufficient strength to light the lamp and to allow the insertion of a resistance for regulation.

The number of watts utilized in a lamp may, of course, be varied, either by increasing the E. M. F. or the amperage of the current, or by decreasing the resistance of the circuit, the latter method being accomplished by the use of a rheostat. It should be remembered, however, that increasing the candlepower beyond that at which a lamp is rated is very injurious and results in a quick deterioration of the same.

36. Using the Lighting Current.—The other means used for operating the diagnostic lamp are the same as those used for the cautery, with the modifications in E. M. F. and current-strength, which have already been mentioned. The transformer shown in Fig. 5 is made both for light and cautery, the coil on the left giving the current for the light and on the right for the cautery. In other cases the current is received directly from the lighting circuit, but may then have to be reduced to the required voltage by means of a rheostat, which is not a very economical method. Rotary transformers may also be used for this purpose, from which a current is received with the correct voltage. When the commercial current cannot be obtained, recourse must be had to a battery, either made up of voltaic cells or storage-cells. Voltaic cells in the form of dry cells have also been used successfully.

37. Portable Battery.—When using voltaic cells for office-work, the gravity, bichromate, and Edison-Lalande cells are all serviceable. For portable purposes the dry cells are the most desirable. The formulas given for combining cells for cautery purposes are also used when calculations have to be made to ascertain the best combination for operating a given lamp. As a lamp of, say, 8 candlepower is made for a voltage varying between 10 and 120 volts, it is well to procure a lamp of a voltage that will be run by a battery of minimum weight, when intended to be portable. If, for instance, the voltage is too high, then a large number of cells are required, which, in case of a storage-battery, would be inconvenient. It would here be better to have the voltage as low as possible in order to require a minimum number of cells. For portable purposes the dry cells are to be preferred. They are not quite as economical as the ordinary cells, but they are very clean, require no attention, and do not deteriorate when not in use. They may be bought in quantities ready for replacing worn-out cells.. This matter of deterioration is quite an item with storage-batteries, and unless they are used very frequently they are rather expensive and troublesome to maintain in good working order.

38. Head-Light.—For diagnostic purposes the lamp is required to light only a limited area, and for this reason it is possible to concentrate the illumination in one direction. Consequently, the illuminative power of the lamp for a given area may be increased fourfold to fivefold, depending on the area and the means used for concentration. It is also of additional advantage to have the operator's eyes shielded from the lamp, in order to study the illuminated parts to the best advantage.

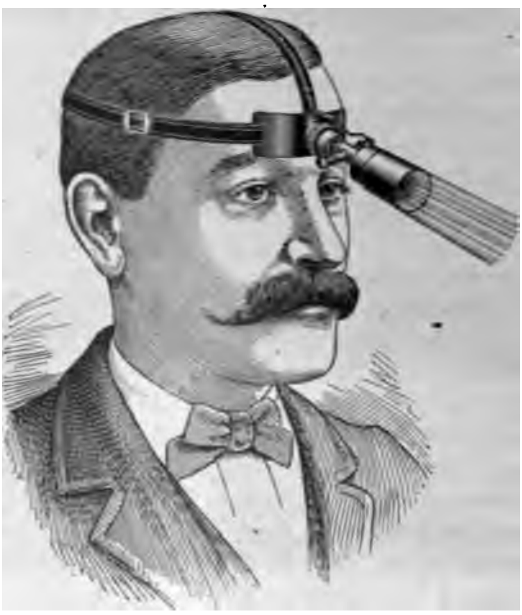

FIG. 13

Such an instrument is shown in Fig. 13, where the lamp with its reflector and condenser is fastened by means of a belt. The operator is then allowed the use of both hands and can also change the direction of the light to suit the requirements. When it is impossible in this manner to throw the light on the parts desired, as, for instance, in throat and nasal examinations, a hand-lamp may be used, as shown in Fig. 14.

39. Cystoscope.—When it is desirable to illuminate cavities and observe the surrounding walls, such as the stomach or bladder, it is necessary to send the light reflected from these walls through a long tube and to enlarge the image thus found by means of suitable lenses. This is done by means of the cystoscope illustrated in Fig. 15. *A* is the lamp situated at the extreme end of the tube *T*. *B* is a prism that receives the image and refracts it through the tube in a longitudinal direction and through a lense placed at *G*, where it is magnified. As the lamp generates some heat, several designs have water circulating through the tube for the purpose of cooling it. The filaments in these small lamps are quite delicate and they should be handled with care to avoid permanent injury.

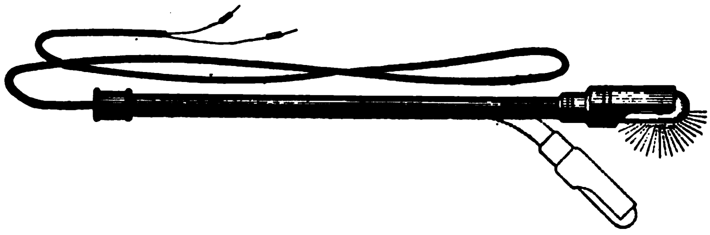

FIG. 14

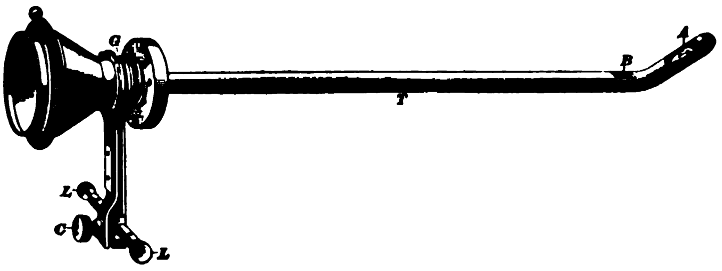

FIG. 15

40. Urethroscope.—Fig. 16 illustrates an improved form of urethroscope in which the lamp is held more securely than in most other forms, and where there is less danger of getting the application entangled with the lamp. The main tube is marked *a* and is provided with an opening at its extremity through which the obdurator *b* projects. The latter is grooved on its under side so as to allow space for the lamp. The tube, obdurator, and lamp are all introduced simultaneously into the urethra, as shown in Fig. 16 (*a*). The handle *h* is provided with studs *f*, to which are attached the conducting-cords from the battery. On the front and rear of the handle are push-buttons *e* for starting and stopping the current. Fig. 16 (*b*), (*c*), (*d*) shows the obdurator, the lamp with its carrier, and the tube *a* without the obdurator. By reason of the position of the lamp there is more direct illumination of the urethra, and the degree of heat imparted to the urethra by the lamp is reduced to a minimum.

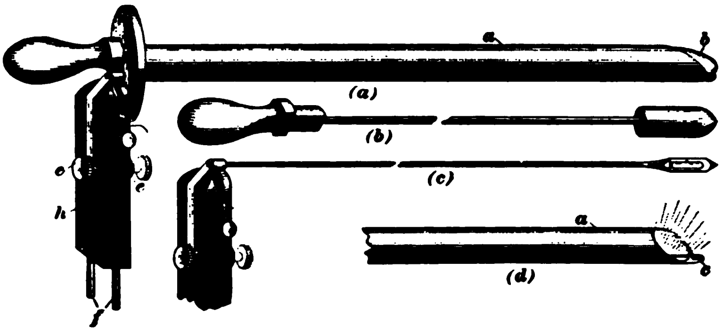

FIG. 16

A SERIES OF QUESTIONS

RELATING TO THE SUBJECTS
TREATED OF IN THIS VOLUME.

It will be noticed that the questions contained in the following pages are divided into sections corresponding to the sections of the text of the preceding pages, so that each section has a headline that is the same as the headline of the section to which the questions refer. No attempt should be made to answer any of the questions until the corresponding part of the text has been carefully studied.

THE PHYSICS OF ROENTGEN RAYS.

EXAMINATION QUESTIONS.

(1) What difference is there between the static machine and other sources of electric energy, as regards the production of Roentgen rays?

(2) Why cannot the current from batteries, dynamos, etc. be used directly for producing Roentgen rays?

(3) What factors determine the strength of an electric current?

(4) Can you name some other instances in nature where these properties play the same role?

(5) What is meant by the electromotive force of a current?

(6) To what does the amperage of a current refer?

(7) What other terms can you name that are equivalent to electromotive force?

(8) Does intensity refer to pressure or rate of flow?

(9) What unit is used to express the power of a current?

(10) What two factors must be known in order to determine the power of a current?

(11) A current with a pressure of 5 volts flows at the rate of 20 amperes. What is its power in watts?

(12) How much greater power has a current of 100 volts and 2 amperes?

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(13) Has the length, sectional area, and interior surface of a tube any effect on the final pressure and flow of water through said tube?

(14) Name the factors that influence an electric current in a similar manner.

(15) How does the temperature of a conductor affect its resistance?

(16) When is a terminal of a battery called positive?

(17) Of what sign is the cathode?

(18) What term is applied to a current that flows in one direction only?

(19) Why is a current called alternating?

(20) What does a source of electric energy really represent?

(21) What is meant by a voltaic cell?

(22) In what direction does the current flow through the negative pole of a voltaic cell?

(23) Is there any pressure in a voltaic cell if no current is flowing through it?

(24) What effect does an increase in resistance have on the current flowing through a circuit?

(25) What effect does the pressure have on the current strength, according to Ohm's law?

(26) How is the current strength found by means of Ohm's law?

(27) If the pressure produced by one cell is insufficient and two cells are required, how should they be connected and what is this combination termed?

(28) If the current strength derived from one cell is too weak and three cells are needed, how must they be connected, and what is the term applied to this combination?

(29) If six cells are to be arranged so as to give a current with a pressure of three cells and a volume corresponding to that of two cells, how should they be arranged, and what combination do they constitute?

(30) If a cell furnishes a current of 3 amperes for 40 hours, how many ampere-hours does it give?

(31) What does an accumulator really store?

(32) What terminal of a storage-battery, when undergoing charging, is connected to the positive terminal of the charging device?

(33) What percentage is usually added to the ampere-hours of a storage-battery when the time of charging is being calculated?

(34) If an accumulator has a capacity of 500 ampere-hours and is charged at the rate of 5 amperes, how many hours are required?

(35) Does the E. M. F. of an accumulator have any effect on that of the charging current?

(36) What is meant by the "gassing" of a storage-battery, and when does it take place?

(37) Why is it important that the rate of charging and discharging a storage-battery be kept within certain limits?

(38) If a lighting circuit is used for charging an accumulator at the rate of 5 amperes, and incandescent lamps are used as resistance, how many 16-candle-power lamps will be required, and how are they arranged?

(39) What is the function of a rheostat?

(40) What purpose does a motor-generator serve?

(41) Why is it that a current of electricity resists a sudden starting and stopping?

(42) If a current, while flowing from left to right in a conductor, is suddenly stopped, what influence will this have on another conductor parallel to the first?

(43) What is meant by an extra current?

(44) What means are used for making the interruption of a current approximately instantaneous?

(45) (*a*) What happens when the armature *H*, Fig. 14, is attracted by the core *C*? (*b*) What path does the extra current follow?

(46) If the gap in a secondary circuit is too large for the closing current to bridge, but small enough for the breaking current, what will be the nature of the current in the secondary coil?

(47) If the diameter of the wire used in the secondary coil is greater than that in the primary coil, and the number of windings is less, how is the pressure in the secondary coil relative to that in the primary?

(48) Is it sufficient to judge the efficiency of a coil simply by measuring its sparking distance?

(49) What determines the power of a coil?

(50) What is the objection to a simple spring interrupter?

(51) In what respect does an independent spring interrupter differ from an ordinary spring interrupter?

(52) How does the rate of interruptions affect the current-strength through the primary coil?

(53) Why is it important that a current should not be sent through the primary coil before the interrupter is in action?

(54) If the discharge of a storage-battery proceeds too far, what effect does it have?

(55) From what part of a Roentgen ray tube do the rays proceed?

(56) What effect does the size of the focusing point have on the sharpness of the skiagraph?

(57) What is the function of the anticathode?

(58) If the vacuum of a tube is varied, what effect has this on the character of the rays?

(59) In order to get the most use from a Roentgen ray tube, what should be the condition of its vacuum when new?

(60) What is the advantage of a self-regulating tube?

(61) To what do the terms "hard" and "soft" refer when applied to a Roentgen ray tube?

(62) To differentiate between dense substances what should be the condition of the tube?

(63) If maximum differentiation is desired in substances of small density, should a soft or a hard tube be used?

(64) If under any conditions maximum differentiation is the aim, what should be the penetrating quality of the rays relative to the density of the integral parts?

(65) What effect has a series spark-gap when inserted in a Roentgen tube circuit?

(66) Does the specific gravity of a substance have any effect on its permeability to Roentgen rays?

(67) What is the relative transparency of glass and lead?

(68) If maximum definition of an object is desirable, what position should it occupy relative to the fluorescent screen or sensitive plate?

(69) When it is required to remove the confusing effect of certain parts, how should they be placed with regard to the sensitive plate?

(70) Should it be of advantage to have all the constituent parts appear with nearly equal definition, what position should the Roentgen ray tube occupy relative to the object?

(71) Do the surroundings of a Roentgen ray tube take any part in radiating Roentgen rays?

(72) What is the cause of the distortive effect of Roentgen rays?

(73) To prevent distortion in a skiagraph of any particular object, what position should the same occupy relative to the tube?

(74) In order to locate a bullet in a body a double exposure has been made while the tube was 14 inches above the sensitive plate. During either exposure the tube occupied a position 6 inches to the left and right, respectively, of the zero point in Fig. 43. The distances between e and f and the center of the plate are 3 and 4 inches, respectively; find the distance of the bullet above the plate and the distance between the bullet and the center line $m_0 n_0$, Fig. 46.

(75) What other means, founded on the motion of the object relative to the Roentgen ray tube, are there for locating the position of an object?

(76) To receive the full benefit of fluoroscopic examination, what should be the condition of the operating room and of the operator's eyes?

SKIAGRAPHY.

EXAMINATION QUESTIONS.

(1) What does a skiagraph really represent?

(2) What means are there at present for making visible the shadows produced by Roentgen rays?

(3) Name the active ingredients in the gelatine coating of a sensitive plate.

(4) Why is a red light used for the dark room?

(5) When handling sensitive plates before exposure and development, what precautions should be taken to avoid misleading marks?

(6) What precautions should be taken when storing sensitive plates?

(7) Why is the sensitive layer of a Roentgen ray plate placed so as to face the tube?

(8) What purpose does the intensifying screen serve?

(9) Does the intensity of the Roentgen rays vary in the same ratio that the distance between the tube and plate is varied?

(10) What other factors, besides distance, affect the length of exposure?

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(11) What is the process of "developing" a sensitive plate?

(12) In covering a plate with the developer, what precautions must be taken?

(13) When an overexposure has been made, is there any difference whether this has been produced by means of a hard or a soft tube?

(14) Why should the aim be to produce contrasts in developing the skiagraph?

(15) If an overexposure has been made, what means should be used to counteract the rapid development of a skiagraph?

(16) If an underexposure has been made and the development proceeds too slowly, what can be done to accelerate the development?

(17) By what signs will a skiagraph indicate an overexposure or an underexposure?

(18) While observing the appearing image of a skiagraph undergoing development, how can a distinction be made as to whether it is overexposed or underexposed?

(19) What precautions should be taken while handling the fixing solution?

(20) What is the difference between a positive and a negative?

(21) In viewing an ordinary negative and a skiagraph from their glassy side, state what difference is found in regard to the position of the integral parts.

(22) In order to, in either case, receive a correct impression of the relative positions of the parts, how should they be viewed?

(23) If a positive is made from a skiagraph, what is there to be said regarding the position of the parts shown in the same?

(24) Explain the difference in perspective between a skiagraph and a picture of the same object.

(25) In viewing a skiagraph from its film side, why are the parts with clear outlines usually overlapped by other parts shown more or less diffusely?

Practical Applications of Roentgen Rays.

EXAMINATION QUESTIONS.

(1) How are the margins of the orbit, the nasal bones, and the antrum Highmori best skiagraphed?

(2) Describe the method of locating a bullet in the eye.

(3) What is the best position of the patient to take a skiagraph of the neck?

(4) What may be said of the value of Roentgen rays in locating foreign bodies in the throat?

(5) What is the special value of the fluoroscope in examining the intrathoracic organs?

(6) Why is the image of the anterior aspect of the ribs diffused in anterior irradiation?

(7) In what position is the heart best skiagraphed?

(8) What may be said of a clear skiagraph of the dorsal vertebræ?

(9) Why are the outlines of the heart better seen during fluoroscopy than in skiagraphy?

(10) What is the advantage of Roentgen rays in the early stage of aortic aneurism?

(11) What may be said of fluoroscopy and skiagraphy in the examination of mediastinal tumors?

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(12) State the value of Roentgen rays in determining the treatment of traumatic pericarditis.

(13) How is a pyothoracic cavity skiagraphed?

(14) How are the outlines of the stomach made visible?

(15) State the principal benefits of abdominal skiagraphy.

(16) What is the most important requisite for skiagraphic success in the diagnosis of cholelithiasis?

(17) In skiagraphing for cholelithiasis, state (*a*) the position of the patient; (*b*) the time of exposure; (*c*) the direction of the rays.

(18) Why must great care be taken to place the tube in the proper direction when exposing for cholelithiasis?

(19) In skiagraphing the kidneys, state (*a*) the quality of the tube used; (*b*) the position of the patient; (*c*) the time of exposure.

(20) State the greatest usefulness of Roentgen rays in renal disease.

(21) Who first skiagraphed a renal calculus?

(22) Is a good skiagraphic plate conclusive evidence in the diagnosis of renal calculi?

(23) What is the chief characteristic of a reliable renal skiagraph?

(24) In what position is a vesical calculus best skiagraphed?

(25) Why should a lateral exposure always be made in skiagraphing for vesical calculus?

(26) How may the outlines of tumors of the stomach be skiagraphed?

(27) State the value of skiagraphy in determining the treatment in spina bifida.

(28) State the use of Roentgen rays in gynecology and obstetrics.

(29) In skiagraphing the pelvis, state (*a*) the position of the patient; (*b*) the quality of tube; (*c*) the time of exposure.

(30) State the difference between the skiagraphs of a normal hip and a hip in the first stage of tubercular inflammation.

(31) State the value of Roentgen rays in the early stage of the different inflammatory processes of the hip-joint.

(32) Describe a skiagraph of arthritis deformans.

(33) State the differences between the skiagraphs of a normal knee-joint and a tubercular knee-joint.

(34) Of what service are Roentgen rays in determining the treatment of osteomyelitis?

(35) What is the characteristic skiagraphic feature of osseous cysts in contradistinction to osteosarcoma?

(36) State the best position to skiagraph (*a*) the metatarsal bones; (*b*) the tarsal bones.

(37) Why should two different skiagraphs in two different positions be always taken in every case of suspected fracture?

(38) What is necessary to always bear in mind in interpreting the skiagraphs of children?

(39) How is a good skiagraph of a shoulder-joint best obtained?

(40) What is the significance of a good skiagraph of a fracture in estimating the degree of functional disability?

(41) What complications of Colles' fracture have the Roentgen rays shown to be of quite frequent occurrence?

(42) If there is no displacement of the fragments, what may be said of the fracture line if the skiagraph is taken immediately after the accident?

(43) What is the quality of the tube required to reproduce the presence of a fissure in bone?

(44) What has skiagraphy proved to be the cause of bony ankylosis following Colles' fracture?

(45) State the services rendered by Roentgen rays in diseases and injuries of the hand.

(46) What may be said of skiagraphy in differentiating the various inflammatory processes from new growths of bones and joints?

(47) When utilizing the rays for therapeutic purposes, state (*a*) the quality of the tube; (*b*) the time of the first exposure; (*d*) the frequency of the exposures; (*e*) the means of protecting the healthy parts.

(48) In what class of diseases is Roentgen ray therapy now generally used?

(49) What qualifications are necessary in order to correctly interpret skiagraphs?

(50) What are the most frequent dental uses of Roentgen rays?

(51) What are the advantages of the film in dental skiagraphy?

(52) At what distance from the film is the tube generally placed in dental work?

Physics of Light and Cautery

EXAMINATION QUESTIONS

(1) Into what forms may the energy of an electric current be changed while passing through a circuit?

(2) What difference is there between the molecules of different substances with regard to the quantity of heat required to heat them to the same temperature?

(3) What influence has the individual weight of a molecule on the number of molecules required to make up a certain mass?

(4) If a certain mass contains a great number of molecules, how will this influence the amount of heat necessary to raise it to a given temperature?

(5) How does the specific gravity of a substance affect the amount of heat that it will take up before it has attained a given temperature?

(6) What is meant by the *specific heat* of a substance?

(7) What is understood by a *calorie?*

(8) If it requires 60 calories to raise the temperature of a platinum wire 10° C., how many calories does it take to produce an equal rise in the temperature of a piece of copper wire of the same weight?

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(9) (*a*) If a current of 10 volts and 5 amperes passes through a conductor, how many calories per second are developed in it? (*b*) How many foot-pounds per second will these calories represent?

(10) A current of 8 amperes passes through a resistance of 2 ohms for 1 minute. How many calories have been developed?

(11) If a conductor first transmits a current of 4 amperes and later on a current of 8 amperes, how many more calories are developed in the latter case?

(12) When the heat developed in one part of a conductor is leaking along the conductor to other parts, by what means does this loss take place?

(13) If the small incandescent lamp of a cystoscope inserted in a cavity of the body heats the surrounding walls, by what means, in this instance, is the heat transmitted to said walls?

(14) How does a resistance-coil of iron or copper heat the surrounding air?

(15) When an electric current is passing continuously through a conductor and constantly transforms part of its energy into heat, what limits, in general, the final temperature that the conductor is able to attain?

(16) A copper conductor having an initial resistance of 120 ohms has its temperature raised 80° C. What increase in resistance has taken place?

(17) If it is desirable to use a conductor whose resistance is unaffected by changes in its temperature, what material would be suitable for such conductor?

(18) If a carbon rod has a resistance of 5,000 ohms, and its conductivity is increased at the rate of .03 per cent. per degree centigrade, what will be the resistance when its temperature is raised 70° C.?

(19) Some salt is added to a vessel of water whereby its resistance is reduced to 500 ohms. Supposing that it suffers a decrease in resistance of .6 per cent. per degree centigrade increase in temperature, what will be its resistance when the temperature of the solution has risen 40° C.?

(20) If part of an electric circuit is heated, has this part any effect on the remaining part of the. circuit, as regards current-strength and temperature? Give reasons.

(21) Part of a heated conductor is suddenly dipped into cold water. What effect has this on the total resistance of the circuit? Does it affect the temperature of the parts not submerged?

(22) What important adjunct should there be in every cautery circuit to insure a constant temperature of the cautery?

(23) If a great number of watts should be dissipated in the form of heat in an electric circuit of low resistance, what other factor must be increased to obtain a sufficient quantity of heat?

(24) If the resistance of a cautery is very low, why is it that the resistance of other parts of the cautery circuit must be still lower?

(25) Is there any objection to having a cautery circuit with a resistance just low enough to give sufficient current to the cautery and with only a small adjustable resistance in the circuit? Give reasons.

(26) What should be the properties of voltaic cells used for cauteries?

(27) A cautery circuit, in which the joint resistance of the cautery and conductors is .04 ohm, is operated by three cells in parallel, each having a resistance of .03 ohm and an E. M. F. of .7 volt. What will be the current-strength in the circuit?

(28) What would be the current-strength if the same cells were arranged in series?

(29) What objection is there to using a direct current from a lighting circuit for cautery purposes?

(30) Mention a method by means of which a direct lighting current may be used economically for cauteries.

(31) Why is the cautery transformer, illustrated in Fig. 5, not as efficient as some other forms where the coils are imbedded in laminated iron?

(32) What precaution should be taken when using a cautery-snare to prevent the overheating of the platinum wire?

(33) A certain incandescent lamp requires 4 watts per candlepower. If the total candlepower is 8 and the voltage 10, what current-strength is required to operate the lamp?

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